SECOR

SECOR INTERNATIONAL INCORPORATED

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September 4, 2003

Mr. Russell Hart
Remedial Project Manager
United States Environmental Protection Agency
Region V
77 West Jackson Blvd
Chicago, Illinois 60604-3590

RE: Quality Management Plan (QMP) Review Comments Response
Southeast Rockford Groundwater Contamination Superfund Site
Area 9/10 Remedial Design

Dear Mr. Hart:

SECOR International Incorporated (SECOR) is in receipt of comments from the United States Environmental Protection Agency (USEPA) regarding the Quality Management Plan (QMP) Equivalent document originally submitted in January 2003 and resent in July 2003 by SECOR to USEPA as part of the fulfillment of the Administrative Order on Consent between Hamilton Sundstrand (HS) and the USEPA for Remedial Design at Area 9/10 of the Southeast Rockford Groundwater Contamination Superfund Site. These comments were dated August 8, 2003 and were authored by Ms. Ida Levin, Quality Assurance Team Leader, Field Services Section, USEPA, in a memorandum to you.

The initial submittal by SECOR was intended to provide an acknowledgement of a quality management system being in place within SECOR and as such did not provide significant detail regarding that system. A copy of SECOR's internal Quality Assurance Manual (QAM) was not provided in that original submittal. This QAM was only referenced (under item 10. Quality Improvement) in the original QMP Equivalent submittal. As such, the responses to the majority of the USEPA's comments are contained within SECOR's QAM. To this end, a copy of SECOR's internal QAM as initially issued in November 2001 is attached. It should be noted that this QAM has been undergoing continued development. The ten basic segments of a QMP as presented in guidance and in the USEPA comments have been cross-referenced as necessary to assist in further review.

The ten segments/sections of the QMP review identified in the USEPA comments are as follows.

1) Management and Organization
2) Quality System Components
3) Personnel Qualification and Training
4) Procurement of Items and Services
5) Documents and Records
6) Computer Hardware and Software
7) Planning
8) Implementation of Work Processes
9) Assessment and Response
10) Quality Improvement

Content for each of these segments/sections within SECOR's QAM are identified, referenced, and annotated as deemed necessary in the sections below.

1) **Management and Organization:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in Section 1. Introduction, and also within SECOR's Quality Management Program Policy and Organization statement (January 2002) as previously submitted (and attached herein as cover to SECOR's November 2001 QAM).

2) **Quality System Components:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in Section 1. Introduction, and also within SECOR's Quality Management Program Policy and Organization statement. Additional information is also contained in other Sections of SECOR's QAM including Section 2. Standard Operating Procedures, Section 3. Project Quality Assurance Planning, and Section 9. Quality Assurance Auditing and Corrective Action.

3) **Personnel Qualification and Training:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM Section 4. Personnel Qualifications and Training.

4) **Procurement of Items and Services:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in Section 5. Subcontractor Quality Assurance and Section 6. Procurement Quality Assurance.

5) **Documents and Records:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in Section 8. Document Control and Recordkeeping, Section 5. Sample Control and Chain of Custody, and Section 15. Technical and Peer Review.

6) **Computer Hardware and Software:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's Quality Management Program Policy and Organization statement such that the Technical Service Program Directors have specific responsibilities. SECOR's Management Information Systems (MIS) personnel have the responsibility of overseeing SECOR's computer hardware and software procurement and use. The MIS personnel have developed standards for hardware for SECOR technical and administrative staff based on their respective position demands. As well, standardized software programs (and version control) are selected and distributed by the MIS group with respect to basic program needs such as word processing, database/spreadsheets, presentations and internet support (e.g. e-mail). Unique or non-standard computer hardware or software requests are managed through the MIS group in terms of verification of need, appropriateness of the application, sustainability of the program, as well as cost effectiveness. SECOR's MIS personnel also provide local area network configuration and support services to the field and corporate locations.

7) **Planning:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM Section 3. Project Quality Assurance Planning.

8) **Implementation of Work Processes:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in Section 2. Standard Operating Procedures, Section 9. Quality Assurance Auditing and Corrective Action, Section 10. Quality Assurance in Sample Collection, Section 11. Field Sampling and Data Collection Methods, Section 12. Guidelines for Planning Sample Analyses, and Section 13. Quality Control for Field Instruments.

9) **Assessment and Response:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in almost all sections of SECOR's QAM. Specifically, Section 9. Quality Assurance Auditing and Corrective Action, addresses this issue. However, it should be noted that in almost every other section of the QMP where procedures to ensure and/or promote quality are presented in an affirmative manner, they are coupled with the understanding (written or otherwise) that if these procedures not followed, appropriate assessment and actions are to be undertaken.

10) **Quality Improvement:** Information pertinent to this segment/section of SECOR's quality management program is depicted in SECOR's QAM in Section 1. Introduction, Section 9. Quality Assurance Auditing and Corrective Acton, as well as SECOR's Quality Management Program Policy and Organization statement.

With the information contained herein in concert with the previous QMP equivalent submittal, the USEPA should be in possession of information to acknowledge the fact that SECOR maintains a quality management system and is committed to that purpose as an organization. Should you have any further questions, please do not hesitate to call.

Sincerely,
SECOR International Incorporated

Angela M. Hagen FOR
David M. Curnock
Principal Scientist

Attachment: SECOR Quality Management Program
SECOR Quality Assurance Manual

cc: Mr. Scott Moyer, HS/UTC
Mr. Eric Alletzhauser, UTC
Mr. Tom Turner, USEPA
Mr. Tom Williams, IEPA
Mr. Terry Ayers, IEPA

SECOR International Incorporated
Quality Management Program
Policy and Organization

Statement

The foundation of SECOR success is our ability to efficiently deliver expert, quality service to our clients. This quality service is maintained through a continuous and dynamic process that strives to foster the highest professional standards of practice. Quality is measured at SECOR in degrees of excellence in our support of our large national accounts as well as our equally important small to mid-size clients.

Policy

Quality management at SECOR is based on a definition of quality as conformity to professional standards, and on the premise that performance requirements are governed by corporate policies, standard operating procedures, safety considerations, and client-specific or project-specific objectives. SECOR is committed to a philosophy that productivity, profitability and client satisfaction result from quality achievement, and that optimum quality is best achieved through a proactive strategy. Quality must be continuously measured by conformity assessment to provide SECOR operations and executive management with recommendations for improvements.

The SECOR Quality Management Program is comprised of these key elements:

- Quality Assurance (QA) - A written set of policies and procedures developed to ensure and document that the work performed achieves the quality requirements of the client and SECOR.

- Quality Control (QC) - A formal and informal system of performance audits, inspections and corrective actions that ensure quality assurance policies and procedures are being followed and/or updated.

The responsibility for maintaining quality of technical operations (both field and office), data collection and analysis, data management and evaluation, documentation and reporting is shared by all operational, technical and management personnel. All work shall be performed in accordance with the standards of our profession and technical expertise, accepted quality practices, and applicable regulations. In absence of specific guidelines, they will follow appropriate scientific or technical judgment.

The SECOR Quality Management Program will be based upon applicable guidelines of the American Society of Quality Control (ASQC), the United States Environmental Protection Agency (and project relevant state and local agencies), and the American Society for Testing and Materials (ASTM). Standards will be traceable to the American National Standards Institute (ANSI), National Institute of Standards and Technology (NIST), and other authoritative reference.

Organization

Ultimately, the responsibility to deliver high quality products and service in a quality manner to our clients is the responsibility of the President and Chief Executive Officer. The Vice President of Technical Programs and Corporate Quality Assurance Officer, in cooperation with the Chief Operating Officer (COO), are responsible for management of the SECOR Quality Management Program as depicted in Figure 1. Technical Service Program Directors are responsible for program development, implementation and maintenance.

Technical Service Program Directors provide technical support to the Regional Managers, National Account Managers and Business Line Managers. Technical program management, project management and client resource management have daily responsibility for the technical resources of the company. Therefore, they are required to assist Technical Service Program Directors in ensuring that the program is implemented and enforced during the routine conduct of all work activities in their regions. Regional program managers and client-project management are responsible for preparation and day-to-day implementation of quality procedures applicable to their work.

The responsibilities of the Corporate Quality Assurance Officer are to:

- Provide overall direction and coordination of the SECOR Quality Management Program and prepare semi-annual status reports for executive management;
- Implement a system to solicit feedback from clients regarding quality of products delivered;
- Render advice and solicit comment to/from corporate, operational, and client management as required to maintain and support the corporate quality management policies and programs;
- Ensure that Standard Operating Procedures (SOP's) are developed and distributed under a document control system;
- Maintain a Library as an archive for QA/QC records and as a distribution center for SOPs;
- Assist Technical Service Program Directors with implementation and maintenance of their technical service-specific quality management programs; and
- Implement and manage the QC portion of the program including periodic performance audits and verification of corrective action.

The responsibilities of the Technical Service Program Directors for their discipline-specific service areas are to:

- Lead the development of their technical service-specific quality management programs;
- Assist the client-project managers in implementation of client-specific QA requirements;

- Ensure SOPs are developed for all quality related functions and distributed to all personnel involved in that function;

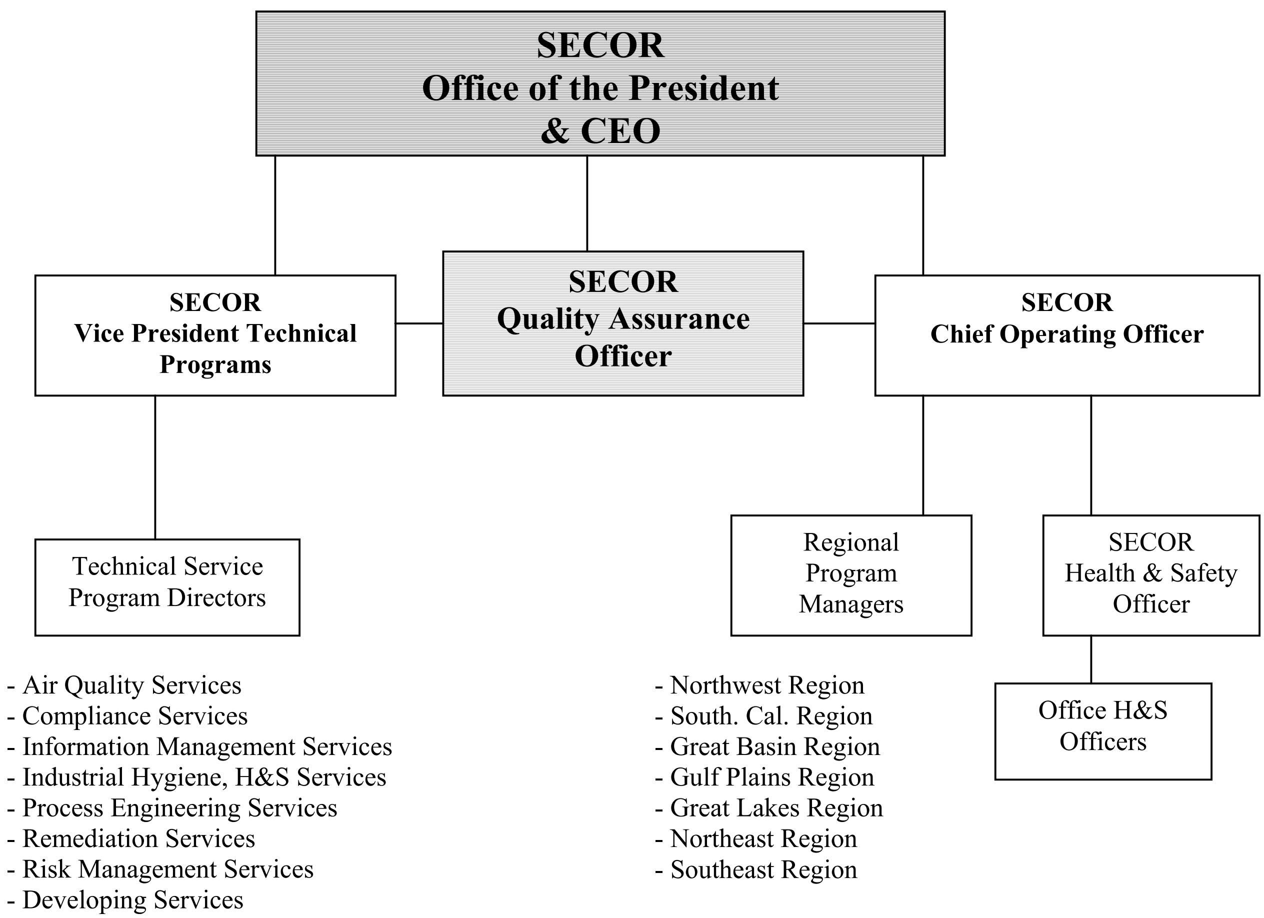
- Monitor performance, provide feedback and training, and revise SOPs as necessary to maintain the desired quality of products and services;

- Actively consult with technical staff and project managers on quality standards applicable to specific projects;

- Report to the Corporate Quality Assurance Officer all quality assurance activities.

FIGURE 1

SECOR QUALITY MANAGEMENT PROGRAM ORGANIZATION



ACCEPTANCE SIGNATURES

SIGNATURE	TITLE	DATE
James Vais	President and Chief Executive Officer	3/7/02
Steve Locke	Chief Operating Officer	3/7/02
Stephen Andersen	Vice President of Technical Programs	1/24/02
James Kerr	Corporate Quality Assurance Officer	02/20/02
James Christopher	Air Quality Services Director	1/29/02
Don Farrell	Compliance Services Director	1/29/02
Robert Braisted	Information Management Services Director	1/31/02
Phillip Platcow	Industrial Hygiene H&S Services Director	3/4/02
Kristine Burgess	Process Engineering Services Director	3/7/02
James Burns	Remediation Services Director	2/01/02
Larry Dziuk	Risk Management Services Director	1/28/02
Daniel Oberle	Research and Development Director	2/04/02

SECOR INTERNATIONAL INCORPORATED
QUALITY MANAGEMENT PROGRAM

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SECOR INTERNATIONAL INCORPORATED
QUALITY ASSURANCE MANUAL

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Purpose and Scope

This document defines SECOR International, Inc. (SECOR) policy and procedures governing the assessment and control of product quality as it pertains to environmental consulting and engineering projects. These projects are defined, for the purpose of this manual to involve the collection, interpretation and reporting of geological, geophysical, hydrological, chemical, ecological, biological, toxicological, socioeconomic, ambient air, and engineering data for the purpose of site characterization, environmental planning and permitting, and selecting and designing remedial measures as well as implementing or supervising the implementation of remedial actions.

It is the goal of this manual to provide a formal system of practical mechanisms for defining the quality objectives, designing the projects to achieve those objectives, critically reviewing performance against the objectives, and assuring SECOR and its clients that the products meet the objectives.

1.2 SECOR Quality Assurance Philosophy and Organization

SECOR's quality assurance policy is based on the definition of quality as conformance to requirements; and further, on the premise that the requirements are governed by corporate policies and standard operating procedures, as well as project-specific objectives.

SECOR is committed to the philosophy that productivity, profitability and client satisfaction result from quality achievement, and that optimum quality can be better achieved through proactive and preventive rather than reactive and curative measures. Quality must also be controlled through adherence to written procedures, and regularly assessed to provide management with recommendations for corrective action. SECOR's Quality Program therefore includes these three aspects:

1) Prevention of defects in quality through planning and design, documented instructions and procedures, and careful selection and training of skilled, qualified personnel;

2) Quality Assessment through a program of regular audits and inspections to supplement continual informal review; and

3) Permanent correction of conditions adverse to quality through a closed-loop corrective action system.

SECOR's policy assigns the primary responsibility for maintaining quality of data collection, processing and analysis, documentation, and report writing to operational personnel. They shall perform their work in accordance with the standards of their profession, accepted quality practices, and applicable regulations. In the absence of specific guidelines, they will proceed according to the best scientific or technical judgment.

SECOR's quality program shall be based upon applicable guidelines and regulatory documents including the American National Standards Institute (ANSI), The American Society of Quality (ASQ), the American Society for Testing and Materials (ASTM) Guidelines, the National Institute of Standards and Technology (NIST), the U.S. Environmental Protection Agency's (EPA) guidelines, and regulations (and project relevant state and local agencies).

The position of Quality Assurance Officer (QAO) in SECOR's organization is illustrated in Figure 1-1. The President and CEO is responsible for fulfilling SECOR's Corporate commitment to assure its clients of quality products and services. The CEO is aided by the Vice President of Technical Programs, Regional Managers, Directors and coordinators, and the Quality Assurance Officer.

Regional and Office Managers and Resource Managers are responsible for facilitating the requirements of this manual in their planning and budgeting, and for implementation of the quality assurance program components as assigned in the Responsibility section of each chapter. Managers may assign Quality Control Officers to assist in implementation.

The responsibility for defining quality goals for individual projects, and implementing quality assurance programs at the project level ultimately rests with the Project Manger.

The responsibilities of the Quality Assurance Officer are to:

1) Provide overall direction to, and coordination of, all SECOR Quality Programs;

2) Render advice and comment to both corporate and operational management required to maintain and effect the Corporate Quality Policy and Programs;

3) Supervise the Quality Control (QC) Officers;

4) Conduct regularly scheduled audits of these Quality Programs, either personally or through the QC Officers;

5) Advise operational managers and Quality Control Officers of deficiencies in Quality Programs or performance thereto;

6) Approve and publish Quality Assurance Manuals and Standard Operating Procedures (SOPs); and

7) Summarize the activities, progress and findings of the QA Program in regular reports to management.

The responsibilities of Regional Quality Control Officers are to:

1) Work with project managers and resource managers to define and articulate quality goals and criteria for projects and operational units or programs;

2) Prepare, or review and approve, quality assurance manuals, SOPs and quality assurance project plans, and distribute them;

3) Conduct seminars and discussions for the purpose of explaining and clarifying QA manuals, plans, and SOPs;

4) Schedule, plan and conduct quality assurance audits of SECOR activities and those of its subcontractors and vendors;

5) Document, monitor and report corrective action status/progress; and perform follow-up checks to ensure that the corrective action is completed and effective;

6) Maintain quality assurance records in a secure, controlled-access location, and organize them according to a standard filing system; assist operations managers and Quality Control Officers in developing organized filing systems for operations;

7) Coordinate peer review;

8) Coordinate the efforts of local Quality Control Officers to effect and maintain the quality control programs for their respective organizational units; and

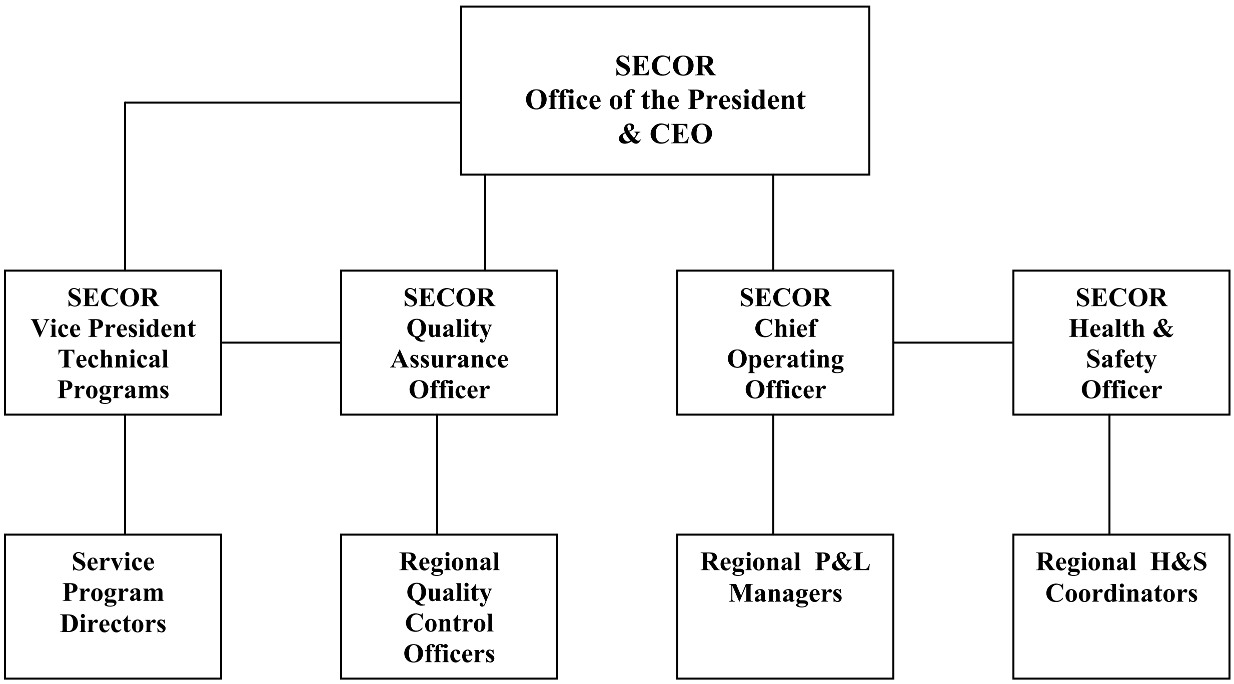
9) Prepare and submit quarterly reports to the Quality Assurance Officer.

For larger projects involving complex measurement programs, or comprehensive technical and peer review or recordkeeping requirements, the project manager may appoint a Project Quality Control Officer, who may be a member of the technical project staff assigned to work with the QA Department to implement the project QA program. The project Quality Control Officer's responsibilities will vary from project to project, and will be described in the project QA plan, but will typically include:

1) Developing the QA plan, distributing it among project personnel and subcontractors, and revising it as necessary, in accordance with Chapter 3 of this manual;

2) Monitoring conformance of project work to the QA plan, and reporting and helping to correct non-conformances;

3) Auditing and/or inspecting subcontractor activities; and



- **Air Quality Services**
- **Compliance Services**
- **Information Management Services**
- **Industrial Health & Safety Services**
- **Process Engineering Services**
- **Remediation Services**

- **Northwest Region**
- **Southwest Region**
- **Great Basin Region**
- **Gulf Plains Region**
- **Great Lakes Region**
- **Northeast Region**
- **Southeast Region**

Figure 1-1
SECOR International, Inc. Organizational Chart

4) Coordination functions such as procurement of analytical services, data validation, instrument calibration, technical and/or peer review, and recordkeeping.

Quality Control Officers are assigned by project managers, PIC's or resource managers to assist in the implementation of the QA program for a specific project or organizational unit. The responsibilities of the Quality Control Officers, for their particular organizational unit, are detailed in that organizational unit's Quality Assurance Manual and/or SOPs, but should include:

1) Assisting the CorporateQA/QC Officer in the preparation of quality assurance manuals and plans;

2) Ensuring that SOPs are developed for all quality-related functions, and are distributed to all personnel involved in those functions;

3) Maintaining a reference library of complete, up-to-date SOPs and project quality assurance plans for their organization;

4) Coordinating recordkeeping, instrument tracking, technical review scheduling, the procurement, maintenance and tracking of standards, and other quality control functions as directed by the responsible project manager, PIC or resource manager;

5) Assuring the safe-keeping and retrievability of records of quality by storing them in a secure, controlled-access location and organizing them according to a standard filing system; and

6) Cooperating with the Quality Assurance Officer and regional Quality Control Officer, and informing them, in advance, of quality assurance activities, such as audits.

1.3 Definitions

Quality Assurance - A system of policies and procedures whose purpose is to ensure, confirm and document that the product or service rendered fulfills the requirements of SECOR and its client. Quality Assurance includes quality planning, quality control, quality assessment (auditing and quality reporting.

Quality Control - A system of checking and corrective procedures, integrated with the activities that directly generate the product or service that serves to monitor and adjust the process to maintain conformance to predetermined requirements.

1.4 Related Documents/Hierarchy of Controls

This section identifies other documents, which play a controlling role in the planning and execution of environmental consulting and engineering work, and delineates the hierarchy of authority among these documents.

Projects often involve chemical analyses of samples. Chemical analyses performed by SECOR are governed by federal and state requirements, which are considered equal to this manual in terms of controlling authority.

Chemical analyses performed by other laboratories subcontracted to or co-contracted with SECOR will be governed by the analytical quality control provisions of the associated project quality assurance plan (see Chapter 3)

- The SECOR Health and Safety Manual.

  The protection of SECOR employees and subcontractors from potentially injurious exposures to toxic or harmful substances and other hazards in the work place must take precedence over all other corporate obligations. Contracts which involve SECOR personnel as active participants in hazardous waste site investigations or remedial activities or other potentially hazardous work shall support, and in no way conflict with, the provisions of the Health and Safety Manual.

- SECOR's Contract with its Clients

  Subject only to the provisions of OSHA health and safety requirements (29 CSR 1910) and the Site Specific Health & Safety Plan, the ultimate authority of control is vested in the contract.

- Project Quality Assurance Plan

  The quality assurance plan for the specific project is the third level of control authority subject only to the provisions of the Health and Safety Requirements and the Contract. The primary purpose of the Quality Assurance Project Plan is to define the quality objectives that apply to the project and to detail quality assurance provisions to satisfy those objectives. It is important that the Quality Assurance Project Plan is consistent with the Quality Assurance Manual. If a particular contract requirement is at variance with the Quality Assurance Manual, the Quality Assurance Project Plan must describe the variance and its significance.

- SECOR Quality Assurance Manual

  This Quality Assurance Manual (with associated SOPs) is the fourth level of control authority, subject to the provisions of all of the above documents.

1.5 Approval, Distribution and Revision Control

In order that this document achieve the goals outlined in Section 1.1, it is necessary that each SECOR employee who has an active role in the execution of project tasks be familiar with the current provisions of this document. It is also necessary that this document represent a consensus among SECOR Management and operational personnel as to the quality level desired and the means to that end.

Prior to its publication as a controlling document, this manual must be approved by the Quality Assurance Officer and the CEO of SECOR International, Incorporated. To obtain such approval, the document proceeds through an iterative process of review and revision, involving the affected managers and their designated representatives. The signature page at the beginning of the manual represents acceptance.

Each time a revision is made to this manual, it must also be approved. The Quality Assurance Officer must approve each revision. If the revision constitutes a complete rewrite of the document, then review and approval by both the Quality Assurance Officer and the CEO becomes necessary. The appropriate approval process will be decided in each case by the Quality Assurance Officer.

2. STANDARD OPERATING PROCEDURES

2.1 Purpose and General Provisions

Standard Operating Procedures (SOPs) are formal, revision-controlled documents that:

1) Define, to SECOR's clients and to regulatory agencies, the methods used by SECOR in the performance of tasks having an effect on the quality of date, findings or conclusions;

2) Provide standard methods for execution and documentation or work, so as to maximize uniformity and reliability of products; and

3) Facilitate coordination among individuals performing separate but interdependent tasks.

SOPs are generated through a cooperative effort among operations and quality assurance personnel. The Quality Assurance Officer coordinates their development, which involves an iterative process of review and revision until they are satisfactory to both Quality Assurance Personnel and the technical reviewers (See Section 2.4).

SOPs describe standard methodologies that may at times be inappropriate for a specific project. In such cases, exceptions to the SOPs are stated in the Project Quality Assurance Plan (Chapter 3), with rationale.

2.2 Responsibilities

2.2.1 The Quality Assurance Officer and Quality Control Officers are responsible for determining, through consultation with technical staff, the activities that require SOPs, and for working with the appropriate technical experts to develop the SOPs.

2.2.2 The Quality Assurance Officer is responsible for obtaining technical review and approval of SOPs, for maintaining control of new SOPs and revisions, and for maintaining an up-to-date distribution list for SOPs.

2.2.3 SECOR personnel are responsible for performing tasks in accordance with applicable SOPs, except as explicitly directed by the relevant project Quality Assurance Plan, contract, or Health and Safety Requirements SECOR personnel are also responsible for assisting Quality Assurance Personnel in designing accurate and practical SOPs and in keeping the SOPs up-to-date.

2.2.4 Technical reviewers of SOPs are responsible for providing review of drafts sent to them, in accordance with Section 3.4 and within the schedule indicated in the request.

2.3. Minimum Contents of SOPs

Each Standard Operating Procedure shall contain at a minimum, the following information:

2.3.1 Title - The name of the concerned task.

2.3.2 Acceptance - The signature of the originator(s), Quality Assurance Officer and appropriate operations management authority to officially adopt the procedure.

2.3.3 Revision - Revision code number and date of issue.

2.3.4 Section 1.0 - Purpose and Applicability - An explanation of the objectives of the procedure, typical applications and limitations.

2.3.5 Section 2.0 - Definitions (if necessary).

2.3.6 Section 3.0 - Health and Safety Considerations - Descriptions of protective equipment, clothing and procedures necessary or prescribed to prevent injury.

2.3.7 Section 4.0 - Quality Assurance Planning Considerations - A discussion of the decisions that must be made on a project-specific basis, pertaining to the material, configurational and procedural specifications in the SOP, giving the variables that affect the decisions; with the provision that these issues must be resolved in each project QC plan.

2.3.8 Section 5.0 - Responsibilities - Identification of the individuals (by title or organizational position) who are responsible for facilitating and performing the tasks governed by the SOP.

2.3.9 Section 6.0 - Training/Qualifications - The skills, experience and educational background required of the person(s) performing the procedure, and any specific training requirements. For each SOP, consideration should be given to requiring proficiency testing. Documentation of training and proficiency testing should be maintained in each individual's personnel file (See Chapter 4).

2.3.10 Section 7.0 - Required Materials - A complete list of the equipment, apparatus, reagents, etc. needed for the procedure; and a list of related, supporting procedural or reference documents.

2.3.11 Section 8.0 - Method - A clear description of the task on a step-by-step basis. The method description should be written clearly enough, and in sufficient detail, to ensure that any two persons performing the procedure will achieve equivalent results, and to provide clients and reviewing agencies with a thorough understanding of the procedure. However, SOPs should not define methodologies in such detail as to impose unnecessary restrictions on the adaptability of a procedure to varying project requirements.

Acceptable and equivalent alternatives should be addressed whenever possible, and described in the same detail. For example, the procedure for purging ground water monitoring wells should describe, in equivalent detail, the bailer method, the surface pumping method, and the downhole pumping method.

2.3.12 Section 9.0 - Quality Control Checks and Acceptance Criteria - An outline of quality control checking procedures, including frequency requirements and acceptance criteria. Acceptance criteria may take the form of an illustration such as a chart of acceptable results with tolerances, or other appropriate forms.

2.3.13 Section 10.0 - Documentation - Detailed forms, worksheets, log sheets, and instructions for thorough, consistent, formatted documentation of the tasks governed by the SOP.

2.4 SOP Development and Approval

New SOPs are prepared by Quality Assurance Personnel when required for a specific project or when requested by operations personnel. SOPs need not be originated by Quality Assurance Personnel. Hand-written or typed drafts may be prepared by any qualified individual, but must be submitted to the Quality Assurance Officer for processing.

The Quality Assurance Officer begins by preparing a typed draft and assigning an SOP Number. The draft is distributed for review and comment to SECOR staff who will be, or who represent, users of the final document. The careful review and recommendations are returned to the Quality Assurance Officer by each reviewer, as a marked-up coy of the draft, with attached notes as necessary. After all technical reviewers have responded their recommendations are incorporated in a new draft. Conflicting recommendations are resolved through discussion with the reviewers.

The second draft is distributed to the technical reviewers for final review. This second review draft is accompanied by a cover page to accommodate approval signatures. General SOPs must be approved by the originator, at least two technical reviewers and the Quality Assurance Officer. Approval is signified by dated acceptance signatures on the SOP cover page.

2.5 Revisions

All SOP revisions must be processed through the Quality Assurance Officer. SOP revisions may be necessitated by regulatory requirements, technological advancements or other causes, but not by the requirements of a single project alone. Contradictions between standard procedures and the requirements of a specific project are resolved in the quality assurance plan for that project (See Chapter 3).

Revisions may be proposed initially by Quality Assurance Personnel, or they may be recommended by users. Recommendations for revisions to SOPs should be sent to the Quality Assurance Officer in the form of a marked-up copy of the existing SOP. Recommendations for minor revisions will be accumulated by the Quality Assurance Officer until sufficient to warrant a revision.

Revisions are initiated with the preparation of a new typed draft with the changes incorporated and listed on the cover page. (The cover page is a permanent document and stays with the SOP despite revisions). Approval of the revisions is signified by dated acceptance signatures adjacent to the listed revisions in the lower section of the cover page. Revisions of SOPs must be approved by at least two technical reviewers and the Quality Assurance Officer. Once formally accepted, the revised document replaces the previous version and is distributed to SOP Manual holders with instructions as to what documents(s) it replaces.

Occasionally, revisions are significant enough to warrant a complete rewrite. In such cases, the changes are not listed on the cover page. Instead the words "complete rewrite" are entered and the new document must undergo review and approval as for a new SOP (Section 2.4). The judgment as to whether a complete rewrite is required shall be made by the Quality Assurance Officer.

2.6 Distribution

The QC Group distributes General SOPs to technical staff and maintains distribution lists to ensure that revisions and new SOPs are distributed to all responsible individuals. Each Regional QC Officer maintains a complete set of up-to-date SOPs and distributes them within his or her region. The central SOP archive is maintained in the Ft. Collins, Colorado office, and SOPs are distributed to the Regional QC Officers from that archive.

2.7 SOP Archive

An archive of all general SOPs, in the form of both hard-copy and electronic masters of current revisions shall be maintained by the Quality Assurance Officer in the Ft. Collins, Colorado office. The hard-copy archive also contains all obsolete versions of each revised SOP.

Access to originals is obtained through the Quality Assurance Officer.

3. PROJECT QUALITY ASSURANCE PLANNING

3.1 Purpose and General Provisions

A project-specific quality assurance plan shall be prepared for each project, to state the objectives and quality goals of the project and to define the mechanisms that will be employed to ensure that those objectives and goals are achieved.

Quality Assurance Planning may range in level of effort from a single-page memorandum to a comprehensive revision-controlled document. The level of effort appropriate for a given project is dictated by several factors, including the study's scope, complexity and objectives, the number of different organizations involved and the probability of litigation or public controversy involving the results of the project.

In the absence of a quality assurance plan for a given project, applicable provisions of this manual shall be considered the project quality assurance program.

The quality assurance plan should be part of, or a partner document to, the work plan (or equivalent) and the health and safety plan for the project, if such documents exist. The quality assurance plan is developed through a cooperative effort among the project manager, task managers for the project and Quality Assurance Personnel. The client may also participate directly in quality assurance plan development.

The quality assurance plan should be developed prior to commencement of work on the project. It should constitute an agreement among the SECOR project and task managers, SECOR Quality Assurance Personnel, subcontractors, client and regulatory agencies as to the organization, schedules and methodology for the project. It ties together the applicable provisions of this manual and Subcontractor quality assurance programs into a unified plan tailored to a specific project.

3.2 Responsibilities

3.2.1 Quality Assurance Personnel are responsible for:

- Assisting the Project Manager in development of the quality assurance plan;

- Review and approval of the quality assurance plan, in cooperation with the Project Manager and the appropriate task managers;

- Auditing to verify conformance with the provisions of the project quality assurance plan; and

- Expediting the preparation of any new SOPs required to make clear the details of tasks to be performed and the criteria for determining quality conformance.

3.2.2 The Project Manager is responsible for:

- Determining the objectives of the project, based on contractual requirements and clarified through discussion with the client; clearly communicating those objectives to the project team; and ensuring that those objectives are addressed in and satisfied by the project QA Plan;

- Providing sufficient resources in the proposal and/or contract to cover the quality assurance planning effort, as well as all required audits, inspections and reviews of procedures, data and reports to ensure validity and conformance to contract requirements;

- Providing sufficient resources in the proposal and/or contract for the appropriate peer, technical, and other reviews; and

- Working with the task managers and Quality Assurance Personnel in the development of an effective workable quality assurance plan.

3.3 Method

3.3.1 A preliminary quality assurance program description should be prepared as part of each technical proposal for environmental consulting and engineering work. This provides a more complete definition of the technical scope of work and ensures that major quality assurance considerations are included in the cost estimate. This preliminary quality assurance program description may be prepared by the proposal manager (or designee) or by Quality Assurance Personnel. Prior to release, each proposal should be reviewed with the appropriate Quality Assurance Personnel and proposed task manager to ensure that the proposed QA program and associated budgets and schedules are adequate.

Upon contract award, and prior to commencement of project work that would be governed by the quality assurance plan, Quality Assurance Personnel and all parties involved in major tasks should review the proposed scope of work and QC program. Refinements are made to:

- Adjust for any differences in project objectives or quality goals between the original proposal and the contract;

- Incorporate subcontractor quality assurance programs (as appropriate);

- Unexpected circumstances that render the plan unworkable in whole or in part, or that alter the objectives of the project.

All project quality assurance plan revisions after approval of Revision 0 shall be performed in accordance with Section 3.4.

3.3.2 The project quality assurance plan must address, as applicable, each of the items outlined below.

a) Project objectives - A summary of the work to be done, and its objectives, from the client's perspective.

b) Quality Goals - Definition of quality for the project, in terms of criteria that will be used to measure how well the work achieves the project objectives. In stating quality goals, it is important to consider the means by which actual quality will be measured, because the results of any assessment depend on the method of the assessment. For example, accuracy assessment data derived from matrix spikes may not compare well to accuracy goals based on surrogate recoveries, even if the analytical program is successful.

c) References to related documents (e.g. the monitoring or sampling plan, site operations plan, contract, EPA Consent Order, etc.).

d) Organization/Responsibilities - A detailed description of the organization of the project team and a summary of the responsibilities of key team members. The role of each key project team member should be clearly defined and detailed enough so that all significant elements of the work plan and quality assurance plan are assigned.

Lines of authority and communication also should be clearly defined. An organization chart should be included.

e) Distribution - A list of personnel required to have a coy of the QA Plan and to implement it.

f) Training - A description of the project-specific training that project personnel will receive, who will provide the training, and any unusual requirements for personnel qualifications.

g) Quality Control of Subcontractors - A list of the tasks to be subcontracted, requirements for qualification of subcontractors, procurement procedures, and assignment of responsibility for inspection and monitoring of subcontractor performance. When laboratory analyses are to be performed, the selected laboratory's quality assurance plan should be included in the SECOR project quality assurance plan (See Chapter 5).

h) Document Control - An explanation of procedures for revising the plan; and a description of documentation to be generated in the course of the project and assignment of responsibility for generating and archiving it.

i) Applicable Standard Operating Procedures - A list of SOPs applicable to the project and discussion of any exceptions to standard procedure that are appropriate for the project, with rationale.

j) Field Methods/Quality Control - A description of methods to be used in accomplishing each task, providing project - specific detail that is not available in the SOPs. Where SOPs allow for optional equipment or procedures, project quality assurance plans and/or work plans should define whether, or which options are to be employed. For example, the plan should specify (as applicable):

- Equipment to be used in advancing borings and collecting surface or subsurface soil samples;

- Sorbents sample volumes, flowrates, elapsed times for ambient air, worker exposure or "fenceline" air monitoring, or source emission testing;

- Construction methods and materials for ground water monitoring wells;

- Sampling apparatus and procedures, including continuous air monitoring instrument start-up and operation, sampler set-up, ground water well purging methods (taking into account known properties of each well, whenever possible), which samples will be filtered in the field, how samples are to be containerized, preserved, labeled, packed and shipped;

- Quality control samples (field blanks, field duplicates or collocated samples, overspikes, etc.) to be collected, how they are collected/prepared, logged, labeled and at what frequency;

- Portable measurement equipment (e.g. meteorological sensors, HNu, OVA, pH meter, etc.) to be used in the project, who is responsible for it, how and when it is to be calibrated; and

- Decontamination materials and procedures for drilling, excavation and sampling equipment, specifying what equipment will be decontaminated, how and when.

k) Laboratory Methods/Quality Control - A description of sample control procedures, measurables of interest, analytical methods to be employed (with rationale), sample storage procedures, allowable holding times, analytical quality control and data validation and reporting requirements. Methods should be selected on the project's data quality objectives, and method descriptions should explain how the selected methods achieve those objectives in terms of detection limit, turn-around time, completeness, accuracy, precision, etc.

l) Data Validation - A description of the review procedures and acceptance criteria to ensure that project quality objectives are achieved.

m) Data Interpretation and Numerical Analysis Checks - a description of procedures with provisions for checking and peer review of any calculations (manual and computer program), maps and reports to be generated. This provision should define more specific requirements than the SOP, if appropriate and should assign the authority for review and approval to a specific individual or position in the project organization.

n) Peer Review Requirements - A description of the specific items (model runs, reports, procedures, etc.) requiring peer review, schedules for their review, and assigned reviewers.

o) Audits and Corrective Action - Auditing procedures required for the project, specifying, where possible, what portions of the project activity will be audited, how and by whom the audits will be conducted, criteria for evaluation, audit reporting procedures and corrective action responsibility and documentation requirements.

3.3.3 Each page of a project quality assurance plan contains the following information:

- Page number;
- Total number of pages in the document;
- Date of issuance (or effective date of revision);
- Document number ("QA" followed by project number); and
- Revision number.

3.4 Revisions

Project quality assurance plan revisions should be processed through, and approved by, the Project QC Officer. On smaller projects that may not have a project QC Officer, the revisions should be approved by the project manager, or his/her designee, with assistance, as needed, from the QC Group. Each project quality assurance plan is a revision-controlled document. The purpose of revision control is to ensure that:

a) The revised document remains consistent with project objectives and quality goals; and

b) All members of the project team are notified of revisions.

A project quality assurance plan can be revised directly by changing and reissuing the plan itself or by issuing an addendum. For extensive revisions, it is usually better to revise the text directly and reissue the plan under a new revision number. A list of revisions, by Section, should be added to the beginning of the plan, right after the cover page.

When a plan is revised by addendum:

- The addendum must be addressed to all of the QA Plan holders listed in the QA plan (item e, Section 3.3.2) who are still involved in the project at the time of the revision;

- The addendum must identify itself as an addendum to the specific plan, citing the plan by document number, revision number, date, and title; and

- Each revision given in the addendum must be accompanied by a reference to the text in the original QA Plan that is being revised or replaced, by citing section number and page number, unless there is no text in the original plan pertaining to matters addressed by the revision.

Each quality assurance plan revision must be accepted by the project manager, all affected task managers and the Project Quality Assurance Officer prior to issuance.

When the revisions have been approved, the revision number is incremented by one and the date is changed to reflect the effective date of the revisions. The revised quality assurance plan is distributed to all project participants listed in the plan (see item in (e) in Section 3.3.2) with a brief summary of the changes.

4. PERSONNEL QUALIFICATIONS AND TRAINING

4.1 Purpose and General Provisions

The validity of collected data and its interpretive analysis depends, in part, on the qualifications and training of the personnel involved. SECOR's policy is to hire personnel on the basis of demonstrated skill and proficiency in each professional area and to provide a commensurate level of training and professional growth. Personnel are assigned to project tasks in accordance with their specific areas of experience and skill.

Periodic general and project-specific training are provided through lectures, seminars, workshops and apprenticeship assignments.

4.2 Responsibilities

4.2.1. The responsibility for hiring personnel with the appropriate qualifications and for ensuring that training and professional growth are provided rests with the Principal-In-Charge (PIC). PICs are responsible for allocating resources for training, for ensuring that the appropriate training is provided, and that records of training are maintained.

4.2.2 The Health and Safety Officer is responsible for providing health and safety training to fulfill the requirements of 29 CFR 1910.120.

4.2.3 Each employee's direct supervisor is responsible for ensuring that the employee receives the training required or appropriate for his/her work assignments, including health and safety training. Supervisors are also responsible for maintaining records of training for their staff.

4.2.4 Project Managers are responsible for assigning appropriately qualified personnel to project tasks, and providing for any required project-specific training in the project budgets and schedules.

4.2.5 Task managers are responsible for implementing any project-specific training required for tasks under their direction.

4.3 Training

4.3.1. Health and Safety Training

A general outline of the health and safety training curriculum is provided in Table 4-1. This is a forty-hour course designed to fulfill the requirements of 29 CFR 1910.120. Each employee who will work on or at hazardous waste sites must receive this forty-hour training prior to that work, and must receive an eight-hour refresher annually. Further, employees involved in the management of hazardous waste site work must receive eight hours of manager training.

The Health and Safety Officer maintains records of health safety training course attendance and issue cards and certificates to all individuals who have completed the required curriculum.

4.3.2 SECOR personnel receive technical training in several forms:

- Direct hands-on training is provided through short-term apprenticeship assignments, to provide a uniform understanding of SOPs;
- Project-specific training is provided by project managers to project technical staff. This level of training reinforces SOPs, and also serves to orient project personnel to the objectives and requirements of the specific project;
- Technical seminars are arranged by resource managers and conducted by senior technical staff. These are available to all employees; and
- Continuing education is encouraged through a progressive tuition reimbursement program and other incentives.

Supervisors should maintain records of training to document the progress of their staff members through all of these processes. PICs provide facilities for training records in the central files (See Chapter 8).

TABLE 4-1
HEALTH AND SAFETY
TRAINING CURRICULUM OUTLINE

Respiratory Protection
- Air Purifying Respirators
- Use and Limitations
- Maintenance
- Fitting Instructions

Protective Clothing and Equipment
- Types (Boots, Coveralls, Gloves, Hard Hats) and Applications
- Materials
- Permeation and Degradation Characteristics
- Typical Ensembles
- Dressing Out

Toxicology
- Routes of Exposure
- Acute Effects (Irritation, CNS Depression, Asphyxiation, etc.)
- Chronic Effects (Carcinogenicity, Organ Toxicity, Mutagenicity, etc.)
- Dose-Response Relationship
- LD 50, LC 50, Occupational Exposure Limits (Safe Levels of Exposure)

Hazard Assessment
- Sources of Information
- Assessment of Degree of Hazard
- Assessment of Risk of Exposure
- Toxic Properties (Route of Exposure, Effects of Overexposure, Exposure Limits) Relating to Hazard Assessment
- Physical Properties (Vapor Pressure, Vapor Density, Solubility) Relating to Hazard Assessment
- Flammability
- Reactivity

Air Monitoring Instruments and Procedures
- HNu, OVA, Combustible Gas/Oxygen Meter, Detector Tubes
- Principles of Operation
- Detection Limits
- Specificity
- Relative Response
- Calibration
- Uses and Limitations

Site Entry and Control Considerations
- Work Zone Theory
- Levels of Protection
- Decontamination
- Buddy System
- Health and Safety Plan
- Specific Site Examples

Optional or Specialized Training
- Air Supplying Respirators - Air Line and Self-Contained Breathing Apparatus (SCBA).
- Hearing Protection
- Heat Stress
- Confined Space Entry Procedures

5. SUBCONTRACTOR QUALITY ASSURANCE

5.1 Purpose and General Provisions

Subcontractor quality assurance is that system of activities which ensures that Products and services obtained from subcontractors fulfill the needs of the project. Procurement Quality Control (Chapter 6) is a similar system governing procurement of equipment or standardized services (e.g. calibration of a voltmeter) from vendors.

SECOR's subcontractor quality assurance program begins with a procurement procedure and continues throughout the course of the subcontract as a program of regular inspection, assessment and reporting of subcontractor performance and progress.

It is the policy of SECOR to establish a formal subcontract agreement with each subcontractor providing a service, regardless of the cost of the service. The purpose of this policy is to ensure that procured services fulfill the needs of the project.

5.2 Responsibilities

5.2.1 PICs are responsible for establishing and maintaining qualified bidder files for commonly subcontracted services.

5.2.2 It is the responsibility of the Proposal Manager to determine those tasks within each proposed project that are to be performed by subcontractors, and to initiate the subcontractor procurement process by obtaining competitive bids when necessary for cost estimates.

5.2.3 The Project Manager is responsible for final selection of subcontractors on the basis of qualifications and price, and for establishing the subcontract agreement in accordance with this chapter.

5.2.4 Task Managers are responsible for inspecting, monitoring and reporting subcontractor performance and progress.

5.2.5 Quality Control Officers are responsible for conducting periodic QA audits of subcontractors providing analytical services, and for providing the resulting subcontractor performance information to the affected PIC(s) and project manager(s).

5.2.6 Project Quality Control Officers are responsible for inspection of the activities of subcontractors in SECOR field operations, and for reporting the results to the project managers.

5.2.7 The Contracts Department is responsible for maintaining, and making available to Project Managers, standard subcontract material addressing insurance, indemnification, warranties and related contractual issues; and for assisting the project manager in finalizing subcontract agreements.

5.3 Selection of Subcontractors

5.3.1 It is essential that subcontractors on SECOR projects be qualified and experienced in the performance of their assigned tasks. The selection of qualified subcontractors may be a time-consuming effort, and would be costly if repeated for every project. To avoid this, SECOR maintains Master Services Agreements (MSA) with drillers, construction contractors, surveyors, geotechnical contractors, and analytical laboratories. A qualified subcontractors list is maintained in the central files in each office (See Chapter 8). Subcontractors required for a specific project may be selected from this list.

CRITERIA FOR QUALIFICATION OF SUBCONTRACTORS

In order to be accepted as a qualified subcontractor and set-up an MSA, an applicant must be able to present objective evidence to satisfy the following criteria listed below.

- Qualifications of Personnel - All personnel should be a level of experience and education commensurate with their responsibilities. Technicians and analysts who perform measurements, analyses, or evaluations, or who operate instruments or equipment must have demonstrated proficiency at the specific procedures to which they are assigned.

- Quality Assurance Program - The applicant must have a quality assurance program appropriate for the quality impact of their role in SECOR projects; and satisfying the intent of this manual, as applicable. Drilling or construction contractors may meet this requirement by providing written commitment to comply with the applicable provisions of SECOR's project QA plan or sign a MSA, which incorporates QA requirements.

- Health and Safety Program - When the work will involve potential exposure to chemical or physical hazards, the subcontractor must have a health and safety program that ensures the fitness of assigned personnel (including capability to use respiratory protection), and in all respects complies with 29 CFR 1910. Drilling construction contractors may meet this requirement by providing written documentation that their employees have all the required training and that they agree to comply with SECOR's project Health and Safety plan.

INFORMATION CONTENTS OF QUALIFIED SUBCONTRACTORS LIST

The Qualified Bidders or MSA contractors' list contains, for each qualified subcontractor, the following information:

- Name of contractor;
- Name(s) of person(s) representing contractor;
- Capabilities - A list of tasks the contractor is qualified to perform;
- Project Experience - A list of SECOR projects in which the contractor has been involved (if any), and an evaluation of the contractor's performance on each of these projects; and
- Certifications - Any certifications that the contractor holds attesting to their acceptability to regulatory agencies.

QUALIFIED SUBCONTRACTOR FILES

A file will be retained in the contract files for each qualified bidder, and will contain the subcontractor's quality assurance program, health and safety program, the results of inspection and monitoring of the subcontractor's performance on previous SECOR projects, and any other pertinent information.

5.3.2 Selection of subcontractors for a specific project may begin in the proposal stage, with the informal solicitation of bids from qualified candidates for the purpose of SECOR's cost estimate. Actual selection of subcontractors may be performed either prior to or immediately following award of contract. In many cases, this involves a competitive bidding process. In obtaining bids, the project manager (or designee) must:

- Prepare and submit to each candidate subcontractor the SECOR technical specifications for the subcontract, defining SECOR and client requirements for scope and schedule of work to be performed, as well as a copy of the terms and conditions portion of the proposed subcontract agreement;
- Review bids and evaluate cost, commitment to schedule, commitment of resources, etc.;
- Review with the Contracts Department any exceptions to the terms and conditions that may have been requested by a potentially successful bidder; and
- Select the most qualified subcontractor, on the basis of cost, technical qualifications, commitment to schedule, terms, etc.

5.3.3 In the event that no appropriate subcontractors are available on the qualified subcontractors list, the selection process in Section 5.3.2 must include determination of qualifications of all bidders. Candidates are requested to submit, with their bids:

- A description of their Quality Assurance program, or written commitment to comply with SECOR's project QA plan;

- A description of their Health and Safety program, and a written commitment to comply with SECOR's project Health and Safety plan.

- A list of relevant project experience, and

- Organization and personnel qualifications, including certifications, licenses, etc.

5.4 Preparation of Subcontract Agreements

Whenever SECOR enters into an agreement with a subcontractor to obtain analytical chemistry, bioassay, geophysical or other measurement data for use in SECOR reports and consulting services, that agreement is formalized in a written document consisting of the components outlined below. Each component of the package must contain language that incorporates the other components by reference.

1) Summary of the subcontractor's scope of work and schedule for delivery - This should include a clear itemization of the work to be done (e.g., the number of samples of each type, and the analyses to be performed on each), the quality objectives, and the delivery date(s) for results. This portion must address the specific technical requirements of the project for which the services are being procured, and must ensure that those requirements will be fulfilled.

2) Detailed Terms and Conditions - The contracts department will provide a subcontract template that is easily adaptable to most subcontracts. This is the vehicle for setting forth prices and rates, payment terms, insurance indemnifications, warranties, and other contractual matters. Penalty clauses for late delivery or technical deficiencies should be included if appropriate.

3) Technical Specifications - For analytical services, it is important that detailed technical specifications be included to tailor the services to the project-specific data quality objectives. This should include, by reference, the SECOR QA Plan and the SECOR Health and Safety Plan, as applicable. The following should be specified, at a minimum:

   - The exact sample preparation and analysis procedures to be followed (included or specifically cited);

   - Quality assurance and quality control procedures, including quantity or frequency and method if not detailed in the cited method(s), (e.g., reagent blanks, method blanks, laboratory duplicates, matrix spikes or overspikes, surrogates, internal standards, recovery standards, check standards, and instrument calibration),

- Data reduction and reporting format

- Limits of acceptability for quality control checks (if not stated in cited method(s)),

- Deliverables - An itemization of the required contents of data packages, to ensure that the packages are complete enough to permit validation by SECOR.

4) Acceptance Signatures - The subcontract agreement package must include acceptance signatures of authorized representatives of both SECOR and the subcontractor (See Section 5.5).

5.5 Execution of the Subcontract Agreement

Once the subcontract package is completed, it must be finalized as a signed agreement between SECOR and the subcontractor. The subcontractor is not authorized to begin work until this has been accomplished. This is accomplished as follows:

5.5.1 For MSA subcontractors, a completed Subcontractor Authorization Form is forwarded to the subcontractor for review and signature. For non-MSA subcontractors, a completed Purchase Order is forwarded to the subcontractor for review and signature. At this point, the subcontractor may have questions. Questions pertaining to the scope of work or technical specifications should be addressed to the project manager. Questions about the contractual terms and conditions are the responsibility of the Contracts Department.

5.5.2 Upon receipt of the completed, signed agreement from the subcontractor, the Project Manager and Contracts Department will review the Agreement, paying special attention to any changes or annotations made by the subcontractor. If the agreement, as returned from the subcontractor is acceptable to both the Project Manager and Contracts Department, the appropriate SECOR representative will sign the Agreement.

If either the Project Manager or the Contracts Department disagree with the package as returned from the subcontractor, all points of disagreement must be resolved before the document is signed.

5.5.3 Once the agreement has been accepted by both SECOR and the subcontractor, work can commence.

5.5.4 The vendor MSA Number or purchase order number must be referenced on all invoices.

5.5.5 The original accepted subcontract agreement is retained in the Contracts Department files, and a copy is kept in the Project File (See Chapter 8).

5.6 Inspection and Monitoring of Subcontractors in the Field

On-going observation and monitoring of subcontractor performance in SECOR field operations shall be the responsibilities of the appropriate SECOR task manager. Periodic inspections of each subcontractor will be performed by SECOR's Project Quality Control Officer, Regional Quality Control Officer, or other designated representatives, to evaluate the level of adherence to the project QA Plan and the project Health and Safety Plan. The individuals responsible for performing these inspections will be identified in those project plans. Inspection should include (as applicable):

- Type and condition of equipment,
- Calibration procedures,
- Calibration records (e.g. traceability of calibrants, certificates for hammer, gauges, etc.),
- Quality Control data and procedures (i.e., is the quality assurance plan being followed, and are quality control results within acceptable limits),
- Personnel qualifications, and
- Documentation

Results of the inspection should be entered in the field notebook or task file and reported on a regular basis to the Project Manager and PIC. The results of all subcontractor inspections shall be filed in the subcontractor qualification and performance files.

Inspection and monitoring of subcontractors providing analytical data must include a thorough review of submitted analytical data packages by a qualified SECOR professional. This review is necessary to confirm that the submitted data conform to the technical specifications set forth in the subcontract agreement.

5.7 Inspections of Subcontract Laboratory Performance

5.7.1 Audits

Analytical laboratories providing measurements and data to be used in SECOR reports, assessments, or recommendations should be audited at least once. Laboratories that participate in SECOR projects regularly or over an extended time period (one year or more) should be audited on an annual basis.

5.7.2 Data Validation

Data obtained from all laboratories will be reviewed as it is received, to confirm that it conforms to the requirements given in the subcontract agreement, and that it fulfills the needs of the project. This review should include (as applicable), but not be limited to, the following:

- Sampling holding times
- Field and laboratory blank levels
- Matrix spike and/or surrogate recoveries (or equivalent measurement of the accuracy or success of the analytical procedure)
- Laboratory duplicates
- Labeling and traceability of the data
- Completeness of the data
- Sample preparation and analysis methods
- The validation should be performed by a member of the SECOR QC staff.

5.8 Disqualification

Subcontractors may be removed from the qualified subcontractors list, at the discretion of the cognizant SECOR PIC, on the basis of any one of the following:

- Habitual failure to meet project budget and schedule commitments,
- Negligence regarding project Health and Safety programs,
- Negligence regarding project Quality Assurance programs,
- Failure to cooperate with audits, or
- Failure to implement or provide satisfactory response to corrective action requests.

6. PROCUREMENT QUALITY ASSURANCE

6.1 Purpose and General Provisions

This chapter describes the system by which procurement of materials and services (other than subcontractors) is controlled to conform to the SECOR quality requirements associated with its intended use. Purchase of materials and services covered by this chapter is controlled by the Purchasing Department.

Analytical and professional services that contribute data or professional expertise to SECOR reports, assessments, or recommendations are subject to the provisions of Subcontractor Quality Assurance, in the previous chapter.

6.2 Responsibilities

6.2.1 The requisitioner is responsible for accurately and precisely describing, on the purchase order, the item or service to be purchased, and for obtaining approval of the expenditure from the appropriate authority. The requisitioner is also responsible for prompt inspection of all delivered items to verify their conformance to the purchase order.

6.2.2 The SECOR Purchasing Department, or delegated purchasing authority, is responsible for executing the purchase order, in accordance with the approved requisition; selecting a vendor (if not specified by the requisitioner), and obtaining delivery of the items and/or services. In most offices, the requisitioner may perform the purchasing function.

6.3 Method

6.3.1 The requisitioner fills out a purchase order, describing in detail the item to be procured, and specifying a vendor.

6.3.2 The requisitioner enters, on the order, the job or office number to be charged for each item.

6.3.3 The requisitioner obtains approval for the expenditures. If the accounts to be charged are overheard expense accounts, the appropriate manager (or designee) must approve. If the accounts to be charged are project numbers, then the appropriate project manager (or designee) must approve. Approval is signified by signature on the purchase order.

6.3.4 The approved requisition is delivered to the Purchasing Department or delegated purchasing authority, if applicable, who selects the appropriate vendor (if not specified by requisitioner) on the basis of quality and price. Requisitioned items or services are not purchased from a vendor other than the one specified by the requisitioner, without prior approval of the change by the requistioner. The Purchasing Department then executes articles or services. In the absence of a SECOR purchasing department or equivalent, the requisitioner executes the procurement.

6.3.5 Upon delivery of purchased instruments, equipment or materials, the Purchasing Department, or delegated purchasing authority, (or, if necessary, the requisitioner) inspects them for conformance to the specifications on the purchase order, with respect to quantity, model or part number, and other observable features.

6.3.6 The requisitioner is responsible for performing functional tests to assure that procured instruments and equipment are in operating condition. Failures should be brought to the attention of the Purchasing Department immediately.

6.3.7 The Purchasing Department, or delegated purchasing authority, (or, if necessary, the requisitioner) will contact the vendor of any instrument or equipment that fails incoming inspection or functional testing and obtain replacement or refunds as appropriate.

7. SAMPLE CONTROL AND CHAIN OF CUSTODY

7.1 Purpose and General Provisions

Environmental consulting and engineering projects often involve the collection, shipping and analysis of numerous samples of various media from different sampling sites requiring an assortment of analyses. Because of the complexity of many sampling plans, a sample control system is essential. A sample control system involves documentation (labeling and record keeping), organizational (assignment of responsibilities) and procedural considerations. SECOR's sample control system for samples requiring laboratory analysis begins in the analytical laboratory, with the preparation of sampling kits; but it is in the field, during sample collection that the most essential aspects of the system operate. Field sample control and chain-of-custody procedures are governed by this manual. Laboratory sample control procedures are governed by the quality assurance program of the laboratory performing the analyses.

7.2 Responsibilities

7.2.1 The laboratory sample custodian is responsible for the assembly of complete sampling kits, as specified in the sampling plan, monitoring plan or QA plan, and for the proper inspection, log-in and storage of incoming samples.

7.2.2 For large sampling programs, a field coordinator will be assigned and will be responsible for supervising the implementation of this procedure in the field. The field coordinator may delegate the function, but not the responsibility, to specific members of the sampling team.

7.2.3 Each member of the sampling team is responsible for following this procedure in collecting and shipping the samples.

7.3 Sample Control Procedures

7.3.1 Sample Containers/Collection Media

The containers and/or sample collection media for each sampling program are specified in SECOR's Quality Assurance plan for that project. Sampling kits are provided to the Field Coordinator by the analytical laboratory. The sampling kits should be enclosed in coolers, and include the appropriate sample containers, collection media (e.g., sorbent or filter cartridges for air samples), chain-of-custody forms and all appropriate shipping blanks and field blanks. The sample containers and/or collection media provided in the sampling kits undergo cleaning and/or other pretreatment either by the laboratory or by the laboratory's

supplier in accordance with SECOR's project quality assurance plan (See Chapter 3), and are packaged by the analytical laboratory's sample custodian. Completed sampling kits are returned to the sample custodian by the field coordinator after the samples have been collected.

7.3.2 Sample Labeling

As samples are collected and containerized, each sample is labeled with the following information:

- Project Number - The specific project number for that project along with the task number if appropriate.

- Sample Location - Description of the place where the sample was taken (e.g., the well, boring or test pit identification);

- Date - A six-digit number indicating the year, month and day of collection;

- Sample Number - A unique identification number which may contain the above information, but which distinguishes among samples collected from the same site at the same time (Recommend: Project # - Sample location - Depth (soil) or date (air and water)).

- Preservative - (If any);

- Sampler - Signature of person collecting the sample;

- Remarks - Any pertinent observations or further sample description.

Quality control samples (blanks, duplicates, etc.) are labeled as above, but are not identified as quality control samples on the labels. Samples that are to be spiked by the laboratory are labeled as "Matrix Spike" (See Chapter 10).

After collection, identification, and preservation, the sample is maintained under the chain-of-custody procedures discussed below.

7.3.3 Sample Logs

In addition to the labeling of the sample containers, a field sample log is maintained by the field coordinator (or designee), in which a complete account is kept of samples collected at each sampling site. The sample log is filled out as soon as possible after, and on the day of, sample collection. Information entered in the log for each sample includes:

- Sampling site identification

- Sample number

- Sample type
- Number of containers per sample
- Sample depth (for soil, surface water)
- Purge volume (for ground water or water supply samples)
- Date and time collected
- Analyses to be obtained
- Names of other persons present during sample collection
- Information about the circumstances of the sampling event that might be useful in the interpretation of data

7.4 Chain-of-Custody Procedures

Chain-of-Custody procedures serve at least two essential purposes:

1) They provide a formalized mechanism for assignment of responsibility for sample integrity, and

2) They provide objective, physical evidence of the possession history and integrity of each sample, from collection, through analysis to data reporting, which supports the validity of the data.

For whole-matrix samples (e.g., consisting of air, water, soil, waste material, construction material, etc.), chain-of-custody procedures begin in the field with the collection and containerization of samples.

For samples collected on an artificial substrate (i.e., sorbent cartridges or filters), chain-of-custody procedures begin in the laboratory where the substrate is prepared for use as a sample collection medium. In the latter case, sampling kits should arrive in the field with chain-of-custody forms already initiated, and must be signed as received by field personnel. Depending on the logistics of the particular sampling program, the existing chain of custody may be maintained throughout sample collection and transmittal to the laboratory; or a new chain-of-custody record may be started for return of the samples to the laboratory. In either case, it must be possible to trace any sorbent cartridge, filter, or other substrate, individually, through the entire round trip.

A sample chain-of-custody form is shown in Figure 7-1.

As soon as each sample has been collected, containerized and labeled, it is entered on the chain-of-custody form. One chain-of-custody form may be used for as many as ten samples but all samples sharing a single chain-of-custody form must be packaged and shipped together. The sampler must complete all of the heading information on the form accurately and legibly. For each sample, the following information is entered:

- Sample identification number must be identical to the identification number on the sample label

- Date and time of sample collection
- Type and quantity of sample
- Number of containers per sample, and
- Analyses to be performed

Quality control samples (blanks, duplicates, overspikes), are entered as above, but not identified as quality control samples on the chain-of-custody record. Samples to be spiked by the laboratory are identified as "Matrix Spike" (See Chapter 10).

The method of shipment, courier name(s) and other pertinent information are entered in the "Remarks" box. A copy of the shipper's waybill or air bill is retained by the last custodian prior to shipment.

Once they have been properly labeled and logged, samples are packaged for shipment (See Section 10.7) and sent to the laboratory with a separate chain-of-custody record sealed into each package. The entire contents of each package must be recorded on the enclosed chain-of-custody record(s); and the samples identified on each chain-of-custody record must be only those contained in the package represented by that record.

Before each package is sealed, two pieces of chain-of-custody tape are selected and their serial numbers entered in the signature box of the appropriate chain-of-custody forms(s), along with the relinquishing person's signature. Once all of the contents (including the chain-of-custody record) are inside the package, it is sealed with fiber strapping tape. The chain-of-custody tape is then affixed to opposite ends of the lid, so that the lid cannot be opened without breaking the chain-of-custody tape. Each chain-of-custody tape is signed and dated by the person sealing the package. Cellophane tape should be affixed over each chain-of-custody seal to protect it from weathering and abrasion. Detailed packing and shipping procedures are given in Section 10.7 of this manual).

When samples are received at the laboratory, the laboratory sample custodian signs the chain-of-custody record as "Received for Laboratory," and enters the date, time, and chain-of-custody seal numbers. The sample custodian should carefully inspect all samples for:

- Intact air-tight seal
- Intact chain-of-custody
- Evidence of alteration or damage to samples or packaging, and
- Completeness of accompanying records

The laboratory's sample receipt record should explicitly state the condition of each incoming sample. The sampling task manager or his/her designee is notified of arrival and condition of each shipment, and of any discrepancies in accompanying paperwork, immediately after log-in inspection. After the

sample log-in is complete, another coy of the chain-of-custody record, which includes laboratory sample numbers and notations of any discrepancies, is sent to the sampler identified on the chain-of-custody form, or to another SECOR person, as instructed. The original chain-of-custody form is filed in the laboratory, with the shipper's waybill or air bill attached.

These procedures must be incorporate in the contractual agreement between SECOR and the laboratory.

CHAIN OF CUSTODY RECORD

Client/Project Name			Project Location		ANALYSES						REMARKS
Project No.			Field Logbook No.								
Sampler: (Signature)			Chain of Custody Tape No.								
Sample No. / Identification	Date	Time	Lab Sample Number	Type of Sample							

Relinquished by: (Signature)	Date	Time	Received by: (Signature)	Date	Time
Relinquished by: (Signature)	Date	Time	Received by: (Signature)	Date	Time
Relinquished by: (Signature)	Date	Time	Received for Laboratory: (Signature)	Date	Time
Sample Disposal Method	Disposed of by (Signature)			Date	Time
Sample Collector	Analytical Laboratory			SECOR	

Figure 7-1 Example Chain-of-Custody Record

8. DOCUMENT CONTROL AND PROJECT RECORDKEEPING

8.1 Purpose and General Provisions

The quantity of supporting documentation required to document the conduct and quality of environmental consulting and engineering projects necessitates the establishment of a formal system for generating, checking, inventory and archiving of documents. This chapter describes SECOR's minimum program for project document control and record keeping as it applies to field data and numerical analysis. Analytical laboratory document control is governed by the Quality Assurance program of the laboratory performing the analyses. Document control as it pertains to distribution and revision of this manual, SOPs and project quality assurance plans is covered in Chapters 1, 2, and 3, respectively. Further description of the standard data forms covered by this chapter and their applicability and instructions for use are contained in Chapter 10, and in the associated SECOR SOPs. Procedures for documentation of numerical analyses are given in SECOR SOP ________.

8.2 Responsibilities

8.2.1 PICs and/or Office Managers are responsible for establishing and maintaining central files for project records, training records, qualified subcontractor files and other important documentation.

8.2.2 An individual may be assigned by the PIC and/or Office Manager at each SECOR office to be the record custodian. It is the responsibility of record custodians to maintain the central files. This is a clerical task.

8.2.3 Project files are assembled by each project team. Each task manager is responsible for assembling all supporting documentation generated in his or her task.

8.2.4 Each person performing a task is responsible for completing the prescribed documentation, submitting it for review if appropriate, and delivering it to the task manager or placing it in the project-task file.

8.2.5 The project manager is responsible for ensuring that this procedure is implemented in his or her projects and for assembling and archiving the completed project file at the end of the project.

8.3 Procedures for Field Records

Table 8-1 lists field documentation media, indicating for each type of documentation the appropriate responsible parties for issuing, executing and archiving. Documentation requirements and format instructions for each task are given in the SECOR SOP for the task, or in the project QA Plan.

8.4 Procedures for Laboratory Records

Laboratory record keeping procedures should be addressed in that laboratory's quality assurance program (See Chapter 5).

8.5 Documentation of Numerical Analyses

All hand calculations, computer program runs and mapping must be documented in accordance with SECOR SOP __________, Numerical Analysis and Peer Review.

Computer program development and qualifications testing and user instructions shall be documented in accordance with SECOR SOP __________, Qualification and Documentation of Computer Programs.

8.6 Files

Files are maintained in a two-tiered system, as follows:

- Project Files are files of records for active projects, and are identified by the project number. They are maintained by the project manager (or designee), and contain all correspondence and reports relevant to the project, a project-task index referencing the project-task files, and all field data, analytical data and numerical analyses.

- Central Files are maintained in a central location within each office, by a person designated as the record custodian. Central files consist of completed project for inactive or closed projects, as well as records that are not specific to projects, such as computer program documentation, training records, and qualified subcontractor files (see Chapter 5).

Within each project file, records should be separated into several basic categories. These are outlined below. A filing system template for large or complex projects is shown in Table 8-2.

I. A. Project Administration
  1) Project Set Up
  2) Financial Management
  3) Contracts

II. A. Communications
  1) Correspondence
  2) Communication Records

III. A. Data
  1) Field Data
  2) Analytical Data
  3) Data Reduction/Analyses

IV. A. Deliverables

1) Work Plans
2) Health & Safety Plans
3) Maps
4) Reports

TABLE 8-1
DOCUMENT CONTROL

ITEM	ISSUED BY	COMPLETED BY	RETAINED BY (ACTIVE PROJECT FILE)	ARCHIVED BY (INACTIVE PROJECT FILE)
Field Notebooks/Logs	Project Manager	Sampling Team	Project Manager	Project Manager
Equipment Calibration Forms	Project Manager	Equipment Operators	Project Manager	Project Manager
Boring Logs	Project Manager	Boring Inspectors	Project Manager	Project Manager
Monitor Well Installation Reports	Project Manager	Boring Inspectors	Project Manager	Project Manager
Sample Logs	Project Manager	Sampling Team	Project Manager	Project Manager
Chain-of-Custody Forms	Lab	Sampling Team/Lab	Project Manager, Lab	Project Manager, Lab
Shipping Forms	Project Manager	Sampling Team	Lab	Project Manager, Lab
Sample Labels	Lab	Sampling Team	N/A	N/A

TABLE 8-2

I. Project Administration
1) Job Set Up
2) Job Status Updates
3) Contact List

II. Financial Management
1) Cost Estimates/Proposals
2) Consultant/Invoices
3) Subcontractor Invoices
4) Expense Reports
5) Equipment Sheets
6) Budget Control

III. Contracts
1) Client Contracts
2) Subcontractor Contracts
3) Purchase Orders
4) Access Agreement

IV. Correspondence
1) Client
2) Consultant
3) Regulators
4) Third Parties
5) Attorneys

V. Communication Records
1) Phone Memos
2) Faxes
3) E-Mails
4) Meeting Notes
5) Memoranda

VI. Field Data, Investigation
1) Permits
2) Borings Logs & Notes
3) Well Installation Forms & Notes
4) Tests (Grain size, slug test, etc.)
5) Survey Data
6) Variance Form
7) Time Delay Form
8) Utility Clearance Downtown

VII. Field Data, Water Level/Sample
1) Groundwater Level Data
2) Sampling Information & Chain of Custody
3) Keys

VIII. Analytical Data
1) Laboratory Reports
2) Soil Vapor Data
3) NPDES Data
4) Data Validation

IX. Remedial System
1) Design
2) Installation

X. Miscellaneous
1) Field Notes
2) Inventory Records/Tank Tests
3) LEL Surveys
4) Area Well Data
5) Site History
6) Manifests
7) Daily Health & Safety Briefing Logs
8) Etc.

XI. Maps, Etc.
1) Maps
2) Photographs
3) Figures

XII. Deliverables and Reports
1) Work Plan
2) Schedule
3) Health and Safety Plan
4) Status Reports
5) Reports
6) Sensitive Receptors Survey
7) Reimbursement Package
8) Other

XIII. Quality Control
1) Data Processing
2) Peer Review Records
3) Audits (Internal/External/Vendor)
4) Corrective Actions

8.7 Retention of Records

On-site central files should contain current and recent records. Off-site facilities may be used for longer-term storage. Each office maintains a records management system suitable for the volume and type of records it generates, to fulfill the retention and retrievability requirements of this Chapter.

The length of record retention time shall conform to applicable regulatory and contractual requirements, whenever they exist. Otherwise, retention time after completion of a project should be seven years. In some cases, SECOR may transfer project records, and attendant retention responsibilities to the client, in which case, written evidence of that agreement must be retained by SECOR for the life of the records.

9. QUALITY ASSURANCE AUDITING AND CORRECTIVE ACTION

9.1 Purpose and General Provisions

Quality assurance auditing refers to the formal assessment of conformance to the quality assurance/ quality control program and the effectiveness of it. Quality assurance auditing is the responsibility of the Quality Assurance Group, and is performed in cooperation with the affected operating group personnel. Actions taken in response to audit findings to remedy or correct deficiencies observed in an audit are referred to as corrective action. The purpose of this chapter is to establish standard procedures for auditing, for the formulation of audit criteria, and for a documented closed-loop corrective action system.

This manual governs auditing and corrective action procedures for all aspects of environmental consulting and engineering projects, excluding analytical laboratory operations.

9.2 Responsibilities

9.2.1 The Quality Assurance Officer is responsible for ensuring that audits are conducted at a frequency and in a manner consistent with the provisions of this manual. The Quality Assurance Officer is also responsible for the selecting and training of qualified personnel to conduct quality assurance audits.

9.2.2 Regional Quality Control Officers are responsible for planning and executing quality assurance audits of the projects and activities in their respective regions. The Quality Control Officers are also responsible for selecting and training technical personnel for participation in audits requiring technical expertise.

9.2.3 Quality Assurance Auditors (who may be a Quality Control Officer, the Quality Assurance Officer, or a technical person assigned to audit a specific activity) are responsible for the scheduling, planning and conduct of audits and for the reporting of results and issuing of corrective action requests.

9.2.4 PICs and Office Managers receive periodic summaries of the status of corrective action requests, and are responsible for taking any necessary action to resolve outstanding items.

9.2.5 Project Managers are responsible for determining and budgeting the appropriate level of quality assurance auditing for their projects, with the advice of the Quality Assurance Group. The project manager is also responsible for assigning responsibility within the project organization for correction of deficiencies and for responding to corrective action requests.

9.3 Auditor Qualifications and Training

Quality assurance auditors must have, at a minimum, the following qualifications:

- Education - Bachelor's or higher degree in science or engineering; preferably, but not necessarily, in chemistry, environmental engineering, environmental science or a related science.

- Experience - Two to five years' professional experience in chemistry, engineering, or in the environmental field, in which skill in the design, implementation and/or critical evaluation of methods and procedures has been demonstrated.

Quality assurance auditors receive training in the following areas, as needed:

- General quality assurance principles,
- The provisions of this Quality Assurance Manual
- Applicable EPA guidelines and regulations (RCRA, CERCLA, etc.)
- The provisions of the SECOR Health and Safety Program,
- First aid and CPR
- Technical aspects of the environmental consulting and engineering activities to be audited
- EPA analytical methods
- Analytical Laboratory Quality Control

9.4 Audit Methods - Project Audits

A project audit addresses all aspects of the project quality assurance plan, this quality assurance manual, and SOPs. Project audits cover both project-specific and general considerations. A project audit may or may not include a laboratory audit (Section 9.5).

9.4.1 Prior to beginning an audit, the quality assurance auditor notifies the Project Manager, in writing, that an audit is planned and requests assistance in scheduling. The audit notification (Figure 9-1) may be used to provide a budgetary cost estimate and a summary of the materials, information and personnel that should be available for the audit. The exact schedule and scope of the audit are tailored to meet specific project and QA needs, and must comply with the project quality assurance plan.

9.4.2 The quality assurance auditor prepares for the audit by reviewing the project quality assurance plan and developing a detailed checklist, covering the following elements, as appropriate to the project:

- Project Organization - Is the project team organized as described in the QA plan and in the work plan?

- Personnel Qualifications and Training - Is there objective evidence that all tasks have been or are being performed by appropriately qualified and trained personnel?

- Subcontractor Quality Control - Do records exist to document selection of subcontractors in accordance with the procedures in Chapter 5 and in the project QA plan?

- Document Control and Recordkeeping - Are the records of correspondence, plans drawings, field and laboratory operations, numerical analyses, and peer reviews readily retrievable, in accordance with Chapter 8? Are the records legible and reproducible?

- Chain-of-Custody - Is there a complete, reproducible, readily retrievable chain-of-custody document for each sample? Were sample coolers or shipping containers sealed with chain-of-custody tape?

SECOR

AUDIT PLAN

To: ____ Date: ________________________________

From: ____
QA Officer

Please be advised that the QA Group is planning to conduct the audit described below. In order to minimize the cost of the audit, it will be prudent to have the requested materials available for review. It may also be advantageous to appoint an individual within your project organization as a project audit coordinator. If the audit schedule conflicts with you plans, please so state in the response section at the bottom of this form and return it to the QA Officer.
Thank you for your help. We look forward to a productive audit activity, the results of which should assist you in the management of your project.

Project: (Name): ______________________________ (Number): ______________________________

Audit Date: ______________ Time: __________ Approximate Duration: ________________________

Estimated Cost: ______________________________________

Requested Materials: ____

____

____

____

____

____

____

____

RESPONSE ____

____

____

____

____

____

____

Figure 9-1 Sample Audit Plan Form

- Operating Procedures - Is there objective evidence that measurement instruments were operated and samples collected in accordance with the project QA plan and attendant SOPs? Is there objective evidence as to whether and how samples were filtered? Preserved?

- Quality Control - Were the appropriate number of field blanks and duplicate samples collected, as required by the project QA plan? Is there objective evidence that sampling equipment was properly decontaminated before collection of each sample? Are there records of calibration and quality-control checks of all field measurement instruments as required by the project QA plan?

- Numerical Analyses - Are all manual calculations, mapping and computer program runs properly documented in accordance with the QA Plan and attendant SOPs? Have calculations and drawings been checked and signed by a reviewer? Were all computer programs used properly qualified?

9.4.3 The project manager should designate a project team member to assist in the audit (project audit coordinator). The project audit coordinator assembles the materials requested in the audit notice and assists the auditor in finding answers to the questions in the audit checklist. If an analytical laboratory is involved in the audit, the Laboratory QC Officer assists in the portions of the audit directed specifically toward the laboratory (Section 9.5).

9.4.4 After the audit checklist has been completed, the auditor(s) reviews the audit findings and makes a note of observed deficiencies. These observations are discussed with the project manager (or designee) and SECOR project audit coordinator in a post-audit debriefing. If an analytical laboratory is involved in the audit, the Laboratory QC Officer also should be present in this debriefing.

9.5 Audit Methods - Laboratory Audits

Audits of laboratories are conducted by select members of the QA Group, with the assistance of the laboratory QC personnel. Audits take two forms - performance audits and systems audits. Performance audits involve submittal of blind spikes to the laboratory by the Quality Assurance Group for assessment of analytical accuracy. Systems audits consist of a thorough review of project procedures and documentation to confirm that work was performed in accordance with the project QA Plan and that adequate documentation exists to satisfy the project requirements.

9.5.1 Performance Audits

When required on specific projects, the Quality Assurance Group provides spikes for analysis as independent check samples (audit standards).

This is done, if practical, whenever an independent measurement of data accuracy is needed, or when the accuracy assessment procedures to be implemented by the laboratory provide insufficient assurance of data accuracy for the needs of the project.

Audit Standards

The QA Department prepares any audit standards that can be prepared readily from relatively non-hazardous, neat materials or certified concentrated standards. In some cases, preparation of reliable audit standards requires special facilities and equipment due to the hazardous nature of the materials and/or the requirement for precise measurement of minute quantities. In such cases, audit standards are obtained from the USEPA Environmental Monitoring and Support Laboratory (EMSL), Cincinnati, Ohio, or from an equivalent source.

The nature of the audit standards and the frequency of performance audits are specified in the Quality Assurance Plan of each project for which performance auditing is required. When practical, audit standards are provided in matrices resembling real project sample matrices, and undergo the full sample preparation and analysis procedure. However, in many cases this is impractical, and it is necessary to submit audit samples as extracts (or extract equivalents), for analysis only. All measurable constituents in the audit standards should be within the expected range of concentrations to be encountered in the real samples (or in the extracts). They must be within the linear calibration range of the analytical equipment to be used.

Documentation

Performance audit standards are submitted to the Laboratory Quality Control Officer by the Quality Assurance Officer or the Quality Control Officer, in the appropriate, labeled containers. The label on each audit standard contains the following information (as applicable):

Contractor-Prepared Standards

- Date Prepared
- Initials of Preparer
- Project Number
- Audit Standard Number
- Analysis to be Performed

EPA-Supplied Standards

- EPA EMSL Identification Number

- Project Number
- Audit Standard Number
- Analytical Method to be Employed

All audit standards submitted to the Laboratory are logged in a bound logbook by the appropriate Quality Assurance Personnel. The following information is entered for each standard.

- Project Number
- SECOR Audit Standard Number
- EPA EMSL identification number (if applicable)
- Date Prepared or Received
- Description of Matrix
- Name and Quantity of each measurable constituent
- Identification and Expiration Date of each Primary Standard Use.
- Identification of any Analytical Equipment Use (e.g., Analytical Balance)
- Date Submitted to Laboratory
- Analytical Method to be Employed

Interpretation of Performance Audit Results

The audit standards are analyzed by the same procedures as the real samples. Analytical results are included in the analytical data packages.

The Quality Assurance or Control Officer obtains the analytical results from the Laboratory Quality Control Officer and compares them to the true concentrations entered for each audit standard in the QA logbook. For each measurable constituent of each audit standard, the Quality Assurance Officer determines the percent difference between true and reported quantity, using the following equation:

$$\Delta\% = \left[\frac{\text{Reported - True}}{\text{True}}\right] \times 100$$

These results are interpreted as the accuracy of analyses represented by the performance audit. These results may be included in the final data report and compared to the accuracy objectives stated in the project QA plan.

9.5.2 Systems Audits

There are two types of laboratory systems audits. Systems audits of laboratory operations (operations audits) are performed at a minimum frequency of once every twelve months. Operations audits address general laboratory operations. Some project quality assurance plans require project-specific laboratory systems audits (project audits). Project audits and operations audits are not interchangeable because of the vast difference in focus.

Systems Audit Procedures

The systems audits are performed by the Quality Assurance Officer or a designated Quality Control Officer. The Laboratory Quality Control Officer participates in the audits as the laboratory's representative. It is the QC Officer's responsibility to provide the auditor with access to relevant data files, facilities and records, and to assist the auditor in obtaining an objective assessment.

Audit checklists are used to ensure that all salient points are addressed and documented. The checklists must be filled out legibly and reproduceably, in ink, by the auditor, and are signed and dated by the auditor when completed. The operations audit checklists should be based on EPA laboratory evaluation criteria. Project audit checklists are drawn from the applicable project quality assurance plans, as well as relevant provisions of the EPA Guidance.

Audit checklists should cover at least the following areas:

- Operations Audit
  - Personnel qualifications and training records
  - Adequacy of laboratory facilities, including work space, lighting, ventilation, and supplies
  - Organization of lab facilities, including cleanliness, chemical storage, and waste disposal
  - Maintenance, calibration and associated recordkeeping for analytical equipment
  - Preparation and traceability of calibration and quality control standards
  - Safety (facility configuration and practices)
  - General operations, including glassware cleaning, inventory and checking of reagents and standards, and storage procedures
  - Recordkeeping, including sample log-in and tracking, traceability of standards, control charts, data packages, and organization of filing system

- Project Audit
    - Sample log-in and chain-of-custody records
    - Sample storage procedures and records
    - Sample preparation and analysis procedures
    - Method validation (where applicable)
    - Control charts
    - Precision and accuracy assessment
    - Method blanks, reagent blanks, duplicates, check samples fortifications, surrogates, etc.
    - Calibration
    - Data packages
    - Analyst qualifications
    - Data validation and reporting

After the audit checklist has been completed, the auditor(s) reviews the audit findings and makes a note of observed deficiencies. These observations are discussed with the project manager (or designee) and the SECOR project audit coordinator in a post-audit debriefing.

9.6 Audit Methods - Continuous Ambient Air Monitoring Programs

As in the case of analytical laboratories, continuous ambient air monitoring programs require two kinds of audits - performance audits and systems audits. Performance audits are conducted on a quarterly schedule to measure the accuracy of collected data, while annual or semi-annual systems audits provide a review of procedures, equipment configuration, probe siting, recordkeeping, personnel qualifications and other systems issues to ensure that a satisfactory QA program is in place.

These auditing requirements are driven by 40 CFR 58, Appendices A and B.

For SECOR air monitoring program, these audits are conducted by, or under the direction of, the SECOR Technical Services Director. All performance audit results for SECOR monitoring programs are processed and published by the QA Group. The QA Group maintains a file of hard-copy records for each audit, including all field data sheets, supporting traceability documents, and checklists.

9.7 Audit Reporting and Corrective Action

Each audit is documented in a written audit report addressed to the manager of the project or operation that has been the subject of the audit. Audit reports should not contain significant

findings that have not been addressed in post-audit debriefings or otherwise discussed with the responsible manager.

Each audit report will contain, at a minimum, the following components:

- Executive Summary - A concise overview giving the date, location, subject, and purpose of the audit; acknowledging the participants; and summarizing significant findings and recommendations.

- Scope - An explanation of the activities, functions, or components of a project or operation on which attention was focused, identifying any significant areas that were not covered.

- Discussion - A discussion of the audit, explaining each finding, its significance, and whenever possible, its root cause. Deviations from plans, policies or SOP should be discussed in terms of whether they were warranted by the circumstances of the project, and why.

- Recommendations - For each audit finding, recommended corrective actions will be provided. These should be formulated through discussion with the cognizant manager and technical personnel involved in the audit project or function.

The audit report is first issued in draft to the SECOR project manager, project audit coordinator (or, in the absence of an audit coordinator, the project personnel who participated in the audit), and Laboratory QC Officer (if applicable), to solicit comments and/or rebuttals. These responses are forwarded, in writing, to the quality assurance auditor. The auditor makes revisions to the draft, on the basis of these responses, at his/her discretion. Any points of disagreement between the QA Group and the project organization are resolved through discussion, if possible, before the final audit report is issued. Written responses to the draft report will be retained in the audit file and may be attached to the final audit report as an appendix.

Final audit reports are filed in the Quality Assurance Library and issued to project management and to corporate management. Items requiring corrective action are documented on a Corrective Action Request Form (Figure 9-2) addressed to the project manager. The Corrective Action Request is a three-part form. The first copy is retained by the QA Department upon issuance.

The project manager receives the original and one copy. When satisfactory progress has been achieved on each requested action, the project manager or designee enters descriptions of actions and results on the form, then retains the copy and returns the original to the QA Department to close the loop.

The Quality Assurance Officer maintains a file of corrective action requests and keeps track of their progress. Unresolved corrective action requests are listed in a Quality Assurance report to management.

SECOR

CAR No.______________

Date: ______________

CORRECTIVE ACTION REQUEST

<table>
<tr><td colspan="2">TO:

FROM:</td></tr>
<tr><td colspan="2">REPORTED CONDITIONS

ANSWER DUE DATE   SIGNATURE</td></tr>
<tr><td colspan="2">REVIEW AND COMMENTS

SIGNATURE</td></tr>
<tr><td>REVIEW AND COMMENTS</td><td>FOLLOW UP ACTION</td></tr>
</table>

Figure 9-2 Sample Corrective Action Request Form

10. QUALITY ASSURANCE IN SAMPLE COLLECTION

10.1 Purpose and General Provisions

Field measurements associated with environmental consulting and engineering projects may be made directly through the use of direct-reading instruments, portable analytical equipment or field-stationed monitoring equipment; or may involve the collection of samples in the field and subsequent analysis in a laboratory. The former kinds of measurements are discussed in Chapter 13 of this manual, and the latter are addressed in this Chapter and in Chapter 11.

Environmental samples may undergo a number of unavoidable changes in the process of collection, transmittal and preparation for analysis; including decompression, temperature changes and exposure to new chemical environments. The effects of these changes can be minimized through proper sample collection and handling techniques. It is probably impossible, however, to eliminate all of these changes. Samples may also be vulnerable to certain avoidable changes, such as contamination or loss, which can be managed and controlled to within tolerable levels.

This chapter describes basic strategies and quality assurance procedures that must be built into each sampling plan to eliminate or minimize, and permit the detection of errors introduced in sample collection and transmittal, and to ensure that measurements are properly documented. Chapter 11 outlines sampling and data collection methods.

Data collection programs for consulting and engineering projects normally are conducted according to pre-established sampling and analysis plans that cover sampling locations, sample quantities, analytical parameters and schedule. A sampling and analysis plan may be included in the quality assurance plan (Chapter 3) or in a project work plan, in which case a separate document is not necessary. Each sampling plan is based on what is known about the environmental system being studied, and what is to be learned. In some cases, little is known about a site when data collection efforts begin, or circumstances (e.g., available time) prohibit the development of a detailed, written plan.

10.2 Responsibilities

10.2.1 The Project Manager is responsible for ensuring that a sampling and analysis plan and quality assurance plan (Chapter 3) are prepared to conform to the provisions of this chapter while fulfilling project objectives. The project manager may delegate this responsibility to the sampling task manager.

10.2.2 The Quality Assurance Group is responsible for assisting in the development of the quality assurance plan and for review and approval of the quality assurance plan.

10.2.3 Members of the sampling team are responsible for collecting the Quality Assurance Samples described in this Chapter, as required by the project QA Plan; and for adhering to the sample packaging, labeling and documentation requirements of this Chapter and associated SOPs.

10.3 Sample Collection Quality Objectives

The purpose of a sample collection quality assurance program is to ensure that measurement data generated in a study are of sufficient quality to permit well-informed and meaningful interpretation, and that they are well suited to the use for which they were intended. The quality of the measurement data can be defined in terms of the following elements:

- Completeness - The adequacy (in quantity) of valid measurements to prevent misinterpretation, detect significant patterns and trends, and to achieve the informational objectives of the study.

- Representativeness - The extent to which discrete measurements accurately depict the greater picture which they are intended to describe. Good representativeness is achieved through careful, informed selection of sampling sites (e.g. location of air monitors, or of surface water, sediment or benthos sampling sites, or depth of monitoring well screens) and analytical parameters; and through the proper collection and handling of samples to avoid interferences and prevent damage, contamination, and loss.

- Accuracy and Precision - The agreement between a measurement and the true value and the degree of variability in this agreement, respectively. Accuracy and precision of data collected in a study depend on the sampling procedures and measurement standards used and the meticulous, competent use of them by qualified personnel.

- Comparability - The extent to which comparisons among different measurements of the same quantity or quality will yield valid conclusions. Comparability among measurements in a study is achieved through the use of SECOR standard procedures and SECOR standard field data sheets.

- Traceability - The extent to which data can be substantiated by hard-copy documentation. Traceability documentation exists in two essential forms: that which links quantitation to authoritative standards, and that which explicitly describes the history of each sample from collection to analysis.

10.4 Sampling and Analysis Plan

Environmental sampling and analysis programs should be planned in advance. The amount of planning needed depends on the complexity of the data requirements. A sampling and analysis plan should be written, commensurate with the magnitude and complexity of the study, and distributed to all sampling team members, and to the laboratory. A sampling and analysis plan need not be prepared as a separate document if it is included in the project quality assurance plan (See Chapter 3). The plan should address, as applicable, the following elements:

- The objectives of the investigation or study, with particular emphasis on what information is to be gained;
- A description of the overall sampling scheme (See below), with rationale;
- The number and location of sampling points;
- The number and location of control or background samples;
- Requirements for blanks, duplicates/replicates, overspikes, etc.;
- The analyses to be performed (physical, chemical, toxicological, biological);
- The laboratory (or laboratories) that will perform the analyses;
- The analytical methods to be used, with rationale;
- The number and size (weight or volume) of samples to be collected for each type of analysis;
- Sample collection methods, specifying sampling equipment configuration, dimensions, and materials of construction, where applicable;
- Field screening procedures and criteria;
- Sample containerization, preservation and transportation procedures; and
- Schedule of work.

The laboratory (or laboratories) should be consulted in designing a sampling and analysis plan, especially if non-routine analyses are to be required. The laboratory should always be notified of sampling program schedules in advance, so that laboratory personnel and physical resources can be scheduled to meet sample holding time limitations and other project requirements.

It is important that the appropriate sampling scheme be used in each study so that the information obtained from the samples will meet the needs of the study. Selection of a sampling scheme usually requires some knowledge of the environment being investigated and what is to be learned about it. For instance, when designing a sampling program for an air or groundwater pollution study, a general idea of the source and probable distribution of pollutants, the ambient air or groundwater flow patterns and seasonal or diurnal variations in these parameters is helpful. Literature searches will often uncover previous studies, or operational data on the sources, from which some of this information can be obtained. When none of these things is known, a preliminary investigation may be necessary, which may involve random sampling. Some of the most common sampling schemes are described below with considerations as to their use.

RANDOM SAMPLING

Random sampling assumes that the chemical, physical, or biological characteristics of the environment under study are normally distributed in space and time. It, therefore, assigns every unit in the population (every possible sampling point) an equal probability of being sampled. Random sampling is not simply the haphazard selection of sampling points and times. Rather, it involves a well-defined procedure for their selection. The environment under study is divided into a three-dimensional grid, and each unit in the grid is assigned a number. The grid spaces to be sampled are then selected using a random number table. This precludes any possibility of consciously or unconsciously favoring certain sampling locations over others.

Random sampling may require a comparatively large number of samples if a statistically valid characterization of the environment is to be obtained.

Random sampling is most appropriate when little is known about the distribution of the constituents or properties of interest in the environment under study, or when these constituents or properties are known to be distributed randomly.

SYSTEMATIC SAMPLING

Systematic sampling is a common approach to monitoring environments that have already been studied or about which much is already known, for the purpose of detecting changes (for example, ground water monitoring around a secure landfill, pre-and-post-operational monitoring of the ambient air or soil chemistry surrounding an incinerator, or evaluation of benthic invertibrate communities upstream and downstream of an effluent discharge). It involves the collection of samples at regular, predetermined intervals in space and time. Due to the cyclic nature of systematic sampling, it should be used with caution in circumstances where cyclic variations may be present in the environment under study. If the sampling becomes phased with the natural variations, biased results will be obtained (for example, collecting surface water or ambient air samples at twelve-month intervals).

STATIFIED RANDOM SAMPLING

Stratified random sampling is useful when known patterns exist in the distribution of the subjects of interest, and the population of possible sampling points can be subdivided into groups that are either chemically, physically, or biologically homogenous or are characterized by random (normal) distribution. A limited number of random or systematic samples can then be taken to represent each group (for example, collection of surface water or ambient air samples in winter, spring, summer and fall). In cases where determination of the variability within a stratum is not required, a composite of grab samples or even a single grab sample may be collected to represent each stratum.

10.5 Quality Assurance Samples

Quality assurance samples are important because they provide information that is used to assess the quality of the data gathered and its limitations (See Chapter 14). The data produced in any sampling program are subject to many sources of random and assignable error, and before drawing conclusions from the patterns visible in the data, it is necessary to determine which of those patterns represent patterns in the sampled population, and which ones were introduced by the collection, containerization, shipment, storage, preparation and analysis of the samples.

The type and quantity of quality assurance samples appropriate for a given study depend upon the informational objectives of the study. For example, a study that is intended to provide quantitation of a variety of chemical constituents in an environment requires a greater volume of quality assurance samples than one in which only qualitative information regarding the absence or presence of a certain chemical constituent is desired. The appropriate level of quality assurance for each project is determined as part of the planning effort, and is documented in both the sampling plan and in the QA plan (See Chapter 3). In each case, the analytical laboratory and the Quality Assurance Group should be consulted.

The method and purpose of each type of quality assurance sample is discussed below.

- Field Blanks/Equipment Blanks - One of the most common sources of error in analytical data is contamination. Contamination can be contributed by improperly or incompletely decontaminated sampling equipment, by exposure to airborne contaminants, or by cross-contamination in handling, shipment and storage. It is often impossible to eliminate contamination entirely, though sampling procedures are designed to minimize it. Field blanks provide a measurement of sample contamination throughout the process of sample collection and analysis.

- Field blanks for water sampling are made by transferring deionized water into a sample container at the sampling site. If a sample collection device is being used (bailer, pump, alpha sampler, etc.), the deionized water should be transferred to the sample container using the freshly decontaminated sample collection device.

- Field blanks should not be confused with (or substituted for) trip blanks (see below), which remain in the sample shipping container throughout the sample collection and transmittal process, and therefore are not exposed to all of the sources of potential contamination to which actual samples are exposed.

- For soil samples, a true field blank is generally not obtainable. Instead, decontamination rinsate samples may be collected and analyzed. The difference in matrices prohibits quantitative use of the results of the decontamination rinsate samples; however, a qualitative assessment of potential contamination, and of the effectiveness of the decontamination procedure, is provided.

The volume and containers and/or packaging for field blanks should be the same as for the samples they are intended to represent. The deionized water used for field blanks should be obtained from the laboratory that is to analyze the samples. In any case, the source of deionized water should be noted in the field notebook and on the sample log for the field blank. The deionized water should be kept in a sealed container and carefully protected from exposure.

For air monitoring projects, field blanks are appropriate for any effort in which solid sorbents or other artificial substrates are used. They are usually collected by putting a representative sorbent cartridge through all of the steps from sorbent clean-up through extraction/desorption and analysis, except sampling. Blank sorbent cartridges must be identical to the associated sample cartridge and must undergo exactly the same pretreatment and handling routine.

A minimum of one field blank should be collected for each day of sampling. Two types of field blanks should be collected:

- Collect a blank at any site where contamination is likely; for example, where local airborne contaminants are expected to be prevalent. These blanks should represent only the sites at which they were collected.

- Collect field blanks at some randomly selected sites to provide an indication of typical contamination associated with the total sample collection and handling process.

- Duplicates - Environmental samples are exposed to many sources of random error from the time they are collected until analytical results are obtained. Not all of the random error is contributed by the sample preparation and analysis procedure. The nature of random error, as opposed to assignable error, is that it affects the precision or repeatability of results. Analytical laboratories measure the random error contribution of the extraction and analysis procedure by extracting and analyzing duplicate aliquots from the same sample. The variability in the procedure is manifest as the difference in analytical results from the two identical aliquots. In order to measure the total random error contribution from preservation and containerization through preparation and analysis, it is necessary to collect and analyze field duplicates. A field duplicate is a pair of samples that are chemically identical at the time of containerization. That is, they have been collected in such a way that the spacial and temporal variations in the sampled population are not present as significant differences between the two duplicate samples. Field duplicates are prepared in several ways. The most appropriate procedure depends upon the type of sample and the analyses to be performed. In any case, the duplicate sample should be collected where significant contamination is most likely present because no information is gained from duplicates with contaminant levels below detection limits.

  Duplicate water samples are collected either by filling two containers simultaneously from the sampling device or by filling a single container with two sample volumes, and then splitting. The latter method requires a clean container, composed of the appropriate material, at least twice the size of the sample containers. It is important to note that either method increases the potential for sample alteration, especially loss of volatiles or exposure to airborne contamination. When collecting VOA samples, or in situations where airborne contaminants are known or suspected to be significant, replicate samples (see below) may be more appropriate than duplicate samples.

Soil samples may contain gradients of chemical constituents. It is therefore necessary to thoroughly mix a quantity of soil and then split the resulting homogenized material to obtain identical duplicates. However, the additional handling of the sample greatly increases the risk of alteration, contamination and loss of volatile constituents. The contamination risk is mitigated through the use of inert containers and implements for mixing and transferring the sample material, but contamination and alteration by exposure to ambient air are difficult to avoid. If airborne contamination is present, or if analysis for volatiles or alterable (e.g., readily oxidized) compounds is to be performed, replicate samples will be more appropriate.

Duplicate samples are typically collected for particulate and sorbent samples through the use of collocated samplers - samplers that are located close enough to each other to represent the same ambient air conditions, but not close enough to interfere with one another. Samples collected on the two co-located samplers over the same time period are considered duplicate samples. Collocated high volume and PUF samplers are usually placed no more than four meters and no less than two meters apart horizontally and at the same elevation above the ground level. Horizontal separation is important for these samplers because of the effects of aerodynamics on particulate collection efficiency. For solid sorbent sampling using charcoal, Tenax® or XAD-2 resin, collocated samplers should be as close together as possible.

For each type of analysis, a minimum of one per twenty samples (or at least one per sampling round) should be collected in duplicate or replicate.

- Replicates - The process of collecting a sample from the environment is a source of error that is not accounted for in the results obtained from duplicate samples. Even if the population being sampled is homogeneous, errors introduced in the collection of the samples can result in differences between any two samples collected in rapid succession from the same sampling point and containerized separately. Such repeat samples are called replicates and can be used to measure the precision of the entire process of sample collection, containerization, preservation, transportation, preparation and analysis. Replicates may substitute for duplicates when the collection of duplicates is inappropriate or impossible.

  It is important to note the distinction between duplicates and replicates, and to avoid recording duplicates as replicates, or vice versa. Replicate samples are two or more separate samples collected from the same sampling point, while duplicates are the equivalent of replicates that have been composited and split. Variations in chemical composition among replicates can be introduced by spacial and temporal variations in the sampled population and by the imprecision of the sample collection procedure, while variations among duplicates can only be introduced by events that occur during or after sample containerization. Replicates are a less effective measurement of sampling and analytical error than duplicates, because it is impossible to separate the contribution of variations in the sampled population from that of random error. The only exception to this is when the sampled population is known to be spacially and temporally homogeneous, and therefore introduces no variations among replicates.

Replicate samples are collected by simply repeating the sample collection and containerization procedure at a sampling site, to obtain two separate samples. The sampling equipment should be decontaminated between replicates.

Replicate soil samples should be collected from the same borehole, as close to the same depth as possible, and within a stratum. Obvious differences in sample matrix should be avoided.

As with duplicate samples, replicates should be collected where measurable contamination is likely to be present. If contaminant levels in the replicates are below detection limits, they cannot be used for data quality assessment.

- Matrix Spikes - Sometimes matrix interferences are a source of assignable error (bias) in analytical results. The only way to measure matrix interferences is to extract and analyze known quantity of analyte in the sample matrix.

  Matrix spikes are performed by spiking one of a pair of duplicate samples with a known quantity of analyte and extracting and analyzing both the spike and the unspiked duplicate. In the absence of matrix interferences, the difference between the analytical results for these two duplicates will yield an acceptable recovery rate for the spike. If matrix interferences are present, their effect on the analytical results for the overspike can be used to quantify their effect on the rest of the samples.

  Matrix spikes also may be used to measure analytical precision. To do this, two spike aliquots and one unspiked aliquot of a sample are analyzed. This is called a matrix spike duplicate.

- Sorbent retention efficiency checks - In cases where cartridges can be placed in tandem in a sampling train, a back up sorbent tube should be placed downstream of each sample cartridge to permit the detection of breakthrough of target compounds. When this is not possible, other retention monitoring methods, such as pre-sampling surrogate spikes, should be used to provide assurance that compounds have been efficiently trapped by the sorbent.

- Trip Blanks - In order to isolate errors introduced by cross contamination of samples during shipment from other sources of error, it is necessary to generate and analyze Trip blanks when samples are to be analyzed for volatile constituents.

  Trip blanks are sample containers that are filled with deionized water in the laboratory and placed in the sample shipping containers (usually coolers) when the sampling kits are assembled. They remain in the shipping containers until the completed sampling kits are received in the laboratory after sample collection, and they are not opened until they are analyzed. The volume of each Trip blank should be the same as the volume of the samples with which it is shipped, and it should be in the same type of container as the samples.

- Split samples - Split samples are duplicates that are analyzed by separate laboratories for purposes of interlaboratory comparison. This is done only when required for a specific project.

10.6 Sample Collection Records

In addition to chain-of-custody records (Chapter 7), detailed records describing the field sample collection effort must be maintained. These records, like chain-of-custody documentation, must be admissible as evidence in legal proceedings. Therefore, they must be signed and dated, written in ink (or, if in pencil, they must be photocopied immediately and the copies signed and dated in ink), and they must be legible. Field sample collection records should be archived in the central files with the rest of the project records at the end of the project.

Available sample collection records are listed in Table 8-1 of this Quality Assurance Manual and in the appropriate SECOR SOP. Chapter 8 describes document control procedures designed to ensure that the records are generated and to prevent their loss. This section provides a brief description of the purpose and required informational content of key field documentation media.

FIELD NOTEBOOKS

At the end of a sampling round, the field notebook should contain a detailed record of the sampling program in the form of signed and dated entries for each day that sampling or related activities occurred. Information that should be entered in the field notebook each day includes (as applicable):

- Date, including year,
- Project name and number,
- Location,
- A list of SECOR, client, agency, and subcontractor personnel on site,
- Relevant weather conditions (especially significant precipitation events, temperature, wind speed and wind direction),
- Any unusual circumstances,
- Communications with client or agencies,

- Subcontractor progress and/or problems, results of subcontractor inspections (Chapter 5),
- Notes regarding any changes to the sampling plan, QA plan or Health and Safety Plan, with the rationale,
- Observations such as species identifications, evidence of biological stress;
- Results of measurements such as sampler flowrate checks; testing results for properties such as sample temperature, pH; secci disk readings; animal or plant counts, etc;
- A list of samples collected (by sample number), sampling points, analyses to be obtained, shipping date, time, and destination;
- Identification of quality assurance samples (blanks, duplicates, spikes, etc.);
- Chain-of-Custody tape numbers and form numbers associated with each batch of samples shipped;
- Sampler or monitoring instrument calibrations;
- Equipment repairs or maintenance;
- Time of occurrence and nature of any malfunctions;
- Calculations - For example, determination of monitoring well volumes, or ichthyoplankton net depth and sample volume;
- List of all photographs taken that are likely to be used as project date, giving a description of the meaning and relevance of each, along with its roll number and frame number.

EQUIPMENT CALIBRATION FORMS

Calibration of sampling pumps or apparatus, and of analytical devices used to make field measurements (gas chromatograph, photionization or flame ionization detector, flow meter, pH meter, etc.) should be recorded in permanent records. The appropriate form for calibration of each device is given in the associated SOP. These forms should be signed and dated and should document:

- Project name and number,
- The identity (name and serial number) of the device being calibrated,
- The identity of the calibration standard,

- The true value of the calibration standard, and
- The corresponding reading of the device being calibrated,
- Notes regarding any adjustments/repairs and final readings.

BORING LOGS/WELL LOGS/TEST PIT LOGS

Boring logs and test pit logs are worksheets that are filled out in the process of drilling a bore hole or digging a test pit for subsurface exploration or monitoring well installation to document the location and dimensions of each exploration and the subsurface materials encountered. Well logs, or monitoring well installation data sheets, are completed for each well installed, as a record of its location, dimensions, configuration, and construction materials. Details on the information to be entered and how it should be entered are provided in the appropriate SECOR SOP.

SAMPLE LOGS

A sample log record should exist for every sample. Sample logs are permanent records of the details of each sample collected. Sample collection data sheets and instructions specific to each type of sample are given in the appropriate SECOR SOPs. Sample logs may consist of a combination of chain-of-custody forms and sample collection data sheets, as long as the necessary information can be retrieved for each sample.

Generally, the following information should be included in sample logs for each sample:

- Date, including year;
- Project name and number;
- Location;
- Name and signature of sample collector;
- Sampling site identification and description;
- Data relevant to sample collection procedure (e.g., monitoring well purge volume, equipment/implements used, etc.);
- Data relevant to each sample, such as depth, volume, recovery, color, texture, start and end times and flow rate readings (air samples) etc.;
- Sample number;

- Analyses sought;
- Date shipped;
- Chain-of-custody form and tape numbers;
- Descriptions of any circumstances that might affect sample representativesness (such as treatment devices upstream of water supply sample collection point).

PHOTOGRAPHS

Photographs should be taken at the discretion of the field personnel to provide descriptive evidence of site conditions, sampling locations, potential interferences, soil strata exposed in test pits, and other relevant information.

Each photograph should be numbered and logged in the field notebook so that the following information is retrievable for each photograph:

- Date, including year;
- Project name and number;
- Photograph roll and frame number;
- Location;
- Purpose;
- Compass direction in which the camera was facing (if applicable);
- Dimensions and position or location of key objects (e.g., diameter and depth interval of rock cores);
- Identification of any key features visible in the photograph;
- Name of photographer.

10.7 Packaging and Shipment of Samples

Samples should be packaged and shipped in accordance with this Section and the appropriate SECOR SOP.

Sample packaging and shipment procedures are generalized in two categories - procedures for environmental samples, and procedures for hazardous waste samples.

Standard procedures for packaging and shipment of samples are necessary for at least the following reasons:

1) To protect persons handling, receiving and unpacking shipped samples,

2) To minimize loss of samples through breakage or delays in shipment,

3) To ensure documentation of sample integrity,

4) To ensure that all shipments comply with applicable Department of Transportation (DOT) regulations (CFR 49) (See Table 10-1.

10.7.1 Methods - Environmental Samples

Environmental samples are samples are samples of air, water, soil, biota, or other natural medium, taken from areas where contamination is expected to be in relatively low concentrations. For the purpose of this manual, environmental samples are those samples whose toxic, flammable, corrosive or otherwise hazardous constituents represent less than one percent by volume.

For environmental samples, the following procedures are applied:

- The samples are packed in a cooler using cushioning material such as bubble wrap, vermiculite, styrofoam pellets, etc. Crushed ice or ice cubes never should be used for packing material.

- Samples that may be caustic or noxious are placed in paint cans with vermiculite before being placed in the cooler. The recipient of the samples must be notified in advance so that proper precautions may be taken when opening the shipping container.

- If the samples are to be kept chilled, watertight bags of ice or, preferably, cold packs are placed over the tops of the sample containers.

- Two pieces of chain-of-custody tape are selected and their numbers entered on the chain-of-custody form, and on the sampling log or in the field notebook.

- The last copy of the completed chain-of-custody form should be kept with the field records. The original and remaining copies of the chain-of-custody form and other associated paperwork are enclosed in a zip-lock bag and placed in the cooler or taped to the inside of the cooler lid.

TABLE 10-1
APPLICABLE DEPARTMENT OF TRANSPORTATION (DOT) REGULATIONS

	Category	Definition	Applicable Regulations
	General		49 CFR 173.1-173.34, 177
1	Radioactive Material	49 CFR 173.389	49 CFR 173.390-173.398
2	Poison A	49 CFR 173.326	49 CFR 173.327-173.337
3	Flammable Gas	49 CFR 173.300	49 CFR 173.300-173.320
4	Nonflammable Gas	49 CFR 173.300	49 CFR 173.300-173.320
5	Flammable Liquid	49 CFR 173.115	49 CFR 173.116-173.149a
6	Oxidizer	49 CFR 173.151	49 CFR 173.152-173.239a
7	Flammable Solid	49 CFR 173.150	49 CFR 173.152-173.239a
8	Corrosive Material (Liquid)	49 CFR 173.240	49 CFR 173.241-173.299a
9	Poison B	49 CFR 173.343	49 CFR 173.344-173.379
10	Corrosive Material (Solid)	49 CFR 173.240	49 CFR 173.241-173.299a
11	Irritating Materials	49 CFR 173.381	49 CFR 173.381-173.385
12	Combustible Liquid (in containers exceeding 100 gallon capacity)	49 CFR 173.115	49 CFR 173.116-173.118a 173.121-173.149a
13	ORM-B	49 CFR 173.800	49 CFR 173.510, 173.800-173.862
14	ORM-A	49 CFR 163.605	49 CFR 173.510, 173.605-173.655
15	Combustible Liquid (in containers having capacities of 100 gallons or less0	40 CFR 173.115	49 CFR 173.116-173.118a, 173.120-173.149a
16	ORM-E	49 CFR 173.1300	49 CFR 173.510

- More packing material is added if needed, and the cooler is sealed with packaging tape. Packaging tape should be wrapped around the cooler perpendicular to the seal in at least two places.

- The two pieces of chain-of-custody tape are affixed over the seal on each side (front and back of lid), and signed and dated. Cellophane tape should be placed over these chain-of-custody seals to protect them from weathering and abrasion.

- The cooler lid is labeled with the name, address and phone number of the destination laboratory and the return address and phone number. The label on the cooler lid also should identify the contents as environmental samples.

- The completed and labeled coolers should be shipped by commercial overnight air to minimize sample holding times.

10.7.2 Methods - Hazardous Waste Samples

This section applies only to samples, and does not provide procedures for transportation of hazardous wastes for any other purpose. Samples are considered hazardous waste samples when they are known or suspected to contain high concentrations of potentially hazardous materials. For the purpose of this manual, hazardous waste samples are defined as those samples whose total concentration of flammable, toxic, corrosive or otherwise hazardous constituents is likely to be equal to or greater than one percent by volume. Any samples collected from waste streams, drums, waste ponds or lagoons, leachates or sludges should be considered hazardous waste samples unless they are know to be non-hazardous.

- It is necessary to determine the DOT classification applicable to the shipment before exact labeling and shipping procedures can be determined. A qualitative knowledge of the composition of the materials is necessary for classification. Table 10-1 contains references for classification and applicable regulations.

- Hazardous waste sample containers should be filled only to about three quarters of capacity, to allow for expansion under changing temperature conditions. If the samples contain concentrated flammable, corrosive or toxic liquids, the sample jars or bottles should be packed in paint cans with vermiculite before being placed in the coolers. The cans should be labeled to identify contents and to indicate the top (e.g., "This End Up").

- Hazardous waste sample containers must contain no more than one quart of liquid.

- Labeling on the shipping package must include:

    - Identification of the contents as "Laboratory Samples"

- The name of the applicable DOT classification (e.g., "Flammable Liquids, N.O.S.")

- Any other labeling required by the applicable DOT regulations.

  ° Hazardous waste samples must be shipped by cargo aircraft or overland - never on a passenger aircraft.

10.7.3 Inspection/Audits

It is the responsibility of the sample custodian to inspect all incoming samples for intact chain-of-custody seals, evidence of damage, and completeness of records (Chapter 7). The condition of each sample should be noted in the sample receipt records.

The Quality Assurance Group will periodically review sample receipt records during systems audits to ensure that the sample packaging and shipping process is functioning properly and that sample receipt records are complete, and to identify any chronic problems.

11. FIELD SAMPLING AND DATA COLLECTION METHODS

11.1 Purpose and General Provision

The previous chapter describes basic planning and quality assurance procedures common to all sampling programs. This chapter provides brief discussions of procedural considerations for sampling aimed at chemical, physical and biological measurements in a variety of environmental media.

11.2 Responsibilities

Members of the sampling team are responsible for collection and transmittal of samples in accordance with the project sampling plan and QA plan, the appropriate SOPs and this Quality Assurance Manual.

11.3 Construction and Excavation

An integral part of sample collection for studies involving subsurface exploration is the digging of test pits, drilling of boreholes and installation of ground water monitoring wells. Proper execution of these activities is essential to the achievement of quality goals in sample collection, particularly in terms of representativeness.

11.3.1 Test Pits and Trenches

Detailed procedures for excavating and logging test pits and trenches are given in the appropriate SECOR SOP. The locations and dimensions of test pits and trenches are considered in the sampling plan, on the basis of existing information about the site and the informational objectives of the investigation. Any deviations from the sampling plan are noted on the test pit logs and in the field notebook, with the rationale.

If soil samples are to be taken from the test pit for chemical analysis, heavy equipment should be steam cleaned before each test pit or trench excavation is started. Samples for chemical analysis should be taken from within the test pit walls, to avoid material that may have come into contact with the equipment.

All subsurface explorations are supervised and logged by a qualified geologist/engineer (See Chapter 4). Subcontractors shall be selected and supervised in accordance with Chapter 5 of this manual.

11.3.2 Soil Borings and Rock Core Drilling

Soil borings, rock core drilling and the associated documentation activities are governed by the appropriate SECOR SOP.

The locations and dimensions of cores and borings and sampling depth intervals should be determined as part of the sampling plan. Any deviations from the sampling plan are noted on the boring/rock core sample logs and in the field notebook, with the rationale.

If chemical analysis of soil samples is to be performed, caution must be exercised to prevent cross-contamination between strata within a boring and between borings. Drilling equipment should be steam cleaned before each boring is started.

Soil borings and rock coring are performed under the supervision of a qualified SECOR Geologist-Engineer (See Chapter 4), who is responsible for completion of all documentation required by the appropriate SOPs. Subcontractors shall be selected and supervised in accordance with Chapter 5 of this manual.

11.3.3 Installation of Ground Water Monitoring Wells

Ground water monitoring wells are installed in boreholes which have been drilled in accordance with Section 11.3.2 and the associated SECOR SOPs. Well installation is governed by the appropriate SECOR SOP. Permeability tests conducted on the completed borehole or on the completed well should conform to the SECOR SOP. New wells should be developed in accordance with the appropriate SECOR SOP.

Well construction materials are selected to minimize interference with chemical analysis objectives, while fulfilling other project objectives. Solvents and hydrocarbon compounds should not be used. Well dimensions and construction materials are determined in advance, as part of the sampling plan. Any deviations from the sampling plan are noted on the ground water monitoring well construction detail and in the field notebook, with the rationale.

Monitoring well components (well screen, riser pipe) are decontaminated, in accordance with the appropriate SECOR SOP, prior to installation. Any filter and sand placed around the well screen must be clean. The source of the sand should be noted in the field notebook. Monitoring well installations shall be supervised by a qualified SECOR Geologist/Engineer (See Chapter 4). The Geologist/Engineer is responsible for thorough documentation of the well installation, including measurements and drawings.

Subcontractors are selected and supervised in accordance with Chapter 5 of this manual.

11.4 Soil and Water Sampling

Project-specific sampling strategy and quality control depends upon many variables. This section provides general principles to be employed in the formulation of project sampling plans and Quality Assurance plans. In all cases, the analytical laboratory that will be receiving samples for chemical, physical, biological, or toxicological analysis needs to be consulted for input to the plans.

11.4.1 Water Samples

Detailed water sample collection methods are given in the appropriate SECOR SOP for Surface Water Sampling Techniques, and Ground Water Sample Collection. These SOPs discuss the apparatus and procedures for collection of samples. This section discusses containerization and preservation procedures, general principles of sample collection, and quality assurance samples. Sample containerization, preservation procedures, general principles of sample collection, and quality assurance samples. Sample containerization, preservation and handling procedures should be planned in advance, as part of the project QA plan (Chapter 3). The laboratory that will analyze the samples should always actively participate in this planning.

SAMPLE CONTAINERIZATION, PRESERVATION, HANDLING

One-liter amber glass bottles are used for non-volatile water samples requiring glass, although clear glass may be used for measureables that are not light-sensitive. Water samples for purgeable organics (volatiles) analysis are collected in 40-milliliter VOA vials. "Poly-Bottles" are typically used for measureables that may be or must be stored in polyethylene, but other equivalent polyethylene containers may be substituted.

Preparation of sample containers prior to sampling is the responsibility of the laboratory sample custodian. Procedures are given in the relevant EPA Guidance.

Samples destined for analysis of volatile constituents must be containerized in such a way that no air space is present in the sealed container. The container is filled to overflowing, capped and inspected for air. If air bubbles are visible, the procedures is repeated until no air can be seen in the sealed container.

The general guidelines for sample containerization and preservation for EPA-approved analytical methods are given in Federal Register, Vol. 49, No. 209, Friday, October 26, 1984, pp 43260-43261. These requirements are summarized in Appendix A of this Quality Assurance Manual. Project-specific sample containerization, preservation, handling and storage strategies should be devised in cooperation with the Analytical Laboratory Quality Control personnel and the Quality Assurance Department, and should be detailed in the project quality assurance plan.

SAMPLE FILTRATION

The appropriateness of filtration depends on the objectives of a particular investigation. The Project Sampling Plan or Project QA Plan should define project-specific filtration requirements. Filtration may be performed in the laboratory, but should take place as soon as possible after collection, especially for ground water samples.

Field filtration may be performed using a Millipore (or equivalent filtration apparatus equipped with a hand or electrical vacuum pump and a 0.45-micron membrane filter. The filtration apparatus and filter membrane should be composed of a material that is not likely to chemically alter the sample with respect to the analytical parameters of interest. A separate filter must be used for each sample. Used filters may also be sent in for laboratory analysis, in which case, they must be containerized, sealed, labeled, and shipped under chain-of-custody procedures. Field and chain-of-custody records should indicated which water sample is associated with each filter sample.

The first 50-100 mil of water should be used to rinse the filtration apparatus, and the resulting filtrate is discarded. Thereafter, the filtrate is collected as sample. An SOP for field filtration of ground water samples for organics analysis is provided.

SAMPLE REPRESENTATIVENESS

Ground water samples are collected only after purging, so that the sample represents the aquifer or water supply being investigated. During monitoring well purging, the temperature, conductivity and pH of the water is observed and recorded. Stabilization of these properties indicates that the purging is complete. Sample collection records indicate the volume of water purged and the volume of the well or distribution system. The volume of a well is the product of the depth of water in the well and the well diameter.

Water supply samples from distribution systems are subject to the same considerations as ground water samples, but the circumstances and objectives of distribution system sampling efforts may vary considerably.

Grab samples from streams usually should be collected at mid-depth in the deepest flow channel. Integrated samples may be collected in the deepest flow channel over a depth interval. When multiple samples are collected from the same stream or river, the sampling point farthest downstream is sampled first, and then sampling proceeds upstream. This prevents cross contamination associated with transportation of disturbed sediments in the flowing water.

Standing water bodies, such as lakes, ponds and reservoirs, are characterized by pronounced spacial and temporary variation. Sampling procedures must represent the circumstances relevant to a specific project. Therefore, no general guidelines for obtaining representative samples are appropriate.

Sampling collection should begin at the least contaminated sampling site (if known) and proceed toward the more contaminated locations.

Decontamination is essential for the avoidance of cross-contamination among samples. All sampling apparatus is decontaminated before use and after each sample is collected, in accordance with the appropriate SECOR SOP.

FIELD SCREENING OF SAMPLES

Field screening is often necessary or desirable in order to prioritize samples for analysis of volatile organic constituents. A portable volatile organic compound analyzer, such as a flame ionization detector (FID) or a photoionization detector (PID), may be used for this purpose. Operating procedures for these devices are provided by the manufacturer. A portable gas chromatograph may be used to obtain more compound-specific data. Due to the limitations of these devices, caution should be exercised not to make decisions based on field screening that conflict with the design of the sampling plan (See Chapter 10, Section 10.4)

Water samples are screened for volatiles by sampling the head space over each sample with the FID or PID and recording the reading. Screening for semi-volatile organics (e.g., PCBs) requires extraction. Field testing kits are commercially available for some compounds, and can be used to obtain valuable (though somewhat crude) screening data. Extracts also may be analyzed using a portable gas chromatograph.

Screening should be done with a duplicate sample, so that the sample to be sent to the laboratory is not exposed to unnecessary handling. This means that at some sampling sites, more than one duplicate sample will be collected. Duplicates collected for lab analysis, referred to below, must be handled in exactly the same manner as the primary sample. Duplicates collected for screening purposes should be disposed of properly after screening.

11.4.2 Soil Samples for Chemical Analysis

Detailed soil sample collection methods are given in SECOR SOPs for Surface Soil Sampling and Subsurface Soil Sampling. This section discusses considerations for sample collection and containerization.

SAMPLE CONTAINERIZATION

Soil samples are typically placed in 8 to 10 ounce, wide-mouth glass jars with teflon-lined screw-on caps. Some chemical constituents are light-sensitive. Samples to be analyzed for those constituents are placed in amber glass jars, or the glass jars are wrapped with foil. Samples that will be analyzed for fluoride are containerized in plastic, rather than glass. Samples to be analyzed for volatile constituents should be containerized leaving as little airspace as possible. Further guidance on sample containerization, preservation and holding times can be found in Appendix A of this Quality Assurance Manual.

Project-specific requirements are addressed in the project sampling plan and/or quality assurance plan.

SAMPLE PRESERVATION

Samples should kept at their in-situ temperature or cooler, until analyzed. Some organic constituents are light-sensitive, and are protected from light by the use of amber glass containers and by storing in a dark location.

SAMPLE REPRESENTATIVENESS

Subsurface soil samples are often retrieved from considerable depths and, like groundwater samples, may be out of equilibrium at surface conditions of temperature, pressure and chemical environment. It is important to obtain and containerize these samples promptly, so as to minimize interaction with the atmosphere. Interference also can be caused by the contact between the sample material and the sampler. If the sample material is cohesive enough, it should be split longitudinally after extraction from the sampler and the sample should be collected from the center of the soil mass. This also may be done in the laboratory.

In some cases, it may be more important to protect the sample from contact with the atmosphere than to avoid material that has come into contact with the split-spoon. In such cases, the sample jar is filled as completely as possible and sealed with paraffin wax.

The analytical laboratory should be consulted for the suggested sampling procedure.

The sampling geologist engineer is responsible for ensuring that the proper sampling method is used and for documenting the depth, sample type, date and time collected and all other relevant information in accordance with SECOR SOPs and Chapter 10, Section 10.6 of this QA Manual.

Surface soil samples are containerized in much the same way as subsurface samples, but they are not considered out of equilibrium at surface conditions; therefore, contact with sampling implements is the dominant source of potential interference.

Decontamination is essential for the avoidance of cross-contamination among samples. All sampling implements for both surface and subsurface soil sampling are decontaminated before use and after each sample is collected, in accordance with SECOR SOPs.

FIELD SCREENING OF SAMPLES

Field screening is often necessary or desirable in order to prioritize samples for analysis of volatile organic constituents. A portable volatile organic compound analyzer, such as a flame ionization detector (FID) or a photoionization detector (PID) may be used for this purpose. Operating procedures for these devices are provided by the manufacturer. A portable gas chromatograph may be used to obtain more compound-specific screening data. Due to the limitations of these devices, caution should be exercised not to make decisions based on field screening that conflict with the design of the sampling plan (See Section 10.4).

Soil samples are screened for volatile organics by placing a duplicate sample in a sample jar (about one-half full), covering with aluminum foil and shaking. This screening duplicate is then allowed to equilibrate to ambient temperature, after which the analyzer probe is inserted through the aluminum foil to sample the air space over the sample.

Screening for semi-volatile compounds (e.g., PCBs) requires extraction. Extracts also may be analyzed using a portable gas chromatograph.

Note that any screening procedure is performed on a special screening duplicate sample. Samples to be sent to the laboratory (including the duplicates discussed below) must never be handled in this manner. Screening duplicates should be properly disposed of after use.

The procedures described above is not always appropriate. Sometimes a good duplicate sample cannot be obtained from a sampler because gradients may exist and compositing may not be desirable. In such cases, screening for volatiles may be performed by sampling the airspace immediately above the sample as soon as the sampler is opened. This procedure is not as sensitive as the procedure described above, but will provide useful results when a good screening duplicate cannot be obtained.

11.4.3 Soil Samples for Geotechnical Analysis

Soil samples for geotechnical analysis are of two basic types - disturbed and undisturbed. Chemical alternation is not a threat to sample representativeness, although it is usually necessary to minimize moisture loss.

Disturbed soil samples are placed in jars, sealed with paraffin wax, labeled and placed in boxes, one boring to a box. Sample depth is noted on each jar and on the boring log. The sample boxes contain dividers to prevent breakage.

Split-spoon samples of cohesive material may be sealed in jars or coated with paraffin wax and sent to the laboratory as undisturbed samples.

Undisturbed samples are usually collected with shelby tubes. To prevent disruption, the samples are kept in the tubes. At least one-half inch of material is cleared from each end of the tube and the ends of the sample are squared off. The tubes are then sealed at both ends with paraffin wax. For shipping, undisturbed soil samples are packed in wooden boxes. The samples are labeled with depths and sample numbers. The sample numbers are entered at corresponding depth intervals on the boring log.

11.4.4 Other Types of Samples

A site investigation may call for sampling of materials other than those discussed above, such as sediments of surface water bodies or liquid waste (See appropriate SECOR SOP).

Containerization, handling, decontamination, shipping, quality control and documentation requirements are the same as for materials discussed above. Procedures for obtaining representative samples depend on the circumstances of a particular study.

11.5 Aquatic Biology Sampling

Because of the highly variable nature of aquatic environments, project-specific work plans and quality assurance plans should be prepared for all aquatic biology sampling programs, to ensure that the studies are conducted in the proper manner. This section provides an overview of the basic sampling requirements for characterization of the following major aquatic ecosystem communities; phytoplankton, periphyton, zooplankton, ichthyoplankton, benthic macroinvertebrates, and fish. The procedures are designed primarily to be used in freshwater systems. However, with proper modification, these basic methods also can be used in coastal marine and estuarine situations. Prior to sample collection, a QA Plan should be prepared in accordance with Chapter 3. Planners should consult with laboratory taxonomists regarding such specifics as sample volume required, appropriate preservation, and type of sample containers. For each of the following sampling procedures, the field data recording procedures discussed in Section 10.6 must be practiced.

11.5.1 Phytoplankton

Phytoplankton are free-floating microscopic algae found in all water bodies. Nannoplankton are phytoplankton smaller than 60 microns. The sampling methods used in a given study are determined by the objectives of the study (e.g., description of phytoplankton community in qualitative or quantitative terms), the type and size of system being sampled (flowing or standing water), and size range of organisms of interest (i.e., nannoplankton, phytoplankton, or both).

Flowing (lotic) systems sampled for phytoplankton usually are large, slow-moving rivers rather than shallow, fast-moving streams. Sample collection usually is accomplished using an alpha-type or a Kemmerer-type sampler for quantitative samples. A 64-µ mesh plankton net can be used for qualitative sampling if nannoplankton data are not required.

Sampling phytoplankton in standing water (lentic systems) with depths exceeding about 4 feet is accomplished by essentially the same procedures as described for large, slow-moving rivers and streams. For shallow (wadeable) water bodies, a calibrated plastic container generally is used to fill sample containers.

SAMPLE CONTAINERIZATION AND PRESERVATION

One liter or more of sample usually is required. Therefore, in order to reduce sample weight and minimize sample breakage, polyethylene or polypropylene bottles are used. Samples usually are preserved in a 1-percent concentration of either Lugols and Meyers M-3 fixative. Sample handling, shipping, and chain-of-custody procedures are described in Chapter 7.

SAMPLE REPRESENTATIVENESS

Quantitative samples from both slow-moving rivers and standing water usually are depth-integrated or depth-stratified. Depth-integrated samples most often are collected from slow-moving rivers, while depth-stratified samples most often are collected from deep, standing water bodies. The purpose of depth-stratified samples usually is to define possible differences in populations due to light penetration, thermal stratification, and possibly chemical stratification (e.g., fresh versus saline). In shallow water bodies, several samples from various locations are taken to characterize the population. For quantitative sampling, at least two replicates at each sampling location should be collected.

SAMPLE AND DATA ANALYSES

Phytoplankton samples are analyzed in a biological laboratory using compound microscopes for identification and enumeration. Data analyses usually include the calculation of density in terms of numbers of cells per unit of volume of water (no./liter). Biomass or biovolume may also be calculated using standard procedures. Samples requiring Chlorophyll a analysis are analyzed according to industry accepted procedures. Chlorophyll a data are expressed in terms of rates of production such as mg/day. In the absence of a SECOR SOP, procedures in Weber (1973) or Standard Methods (APHA 1985) should be used.

Species diversity indices also may be calculated, as well as a variety of other biotic indices. The study objectives should be reviewed, and the project work plan and/or QA plan should be consulted before these indices are calculated.

11.5.2 Periphyton

Periphyton are microscopic algae that grow attached to submerged, stable substrates such as rocks, trees, and debris. Sampling from natural substrates may be either quantitative or qualitative. Samples also may be collected on artificial substrates, which usually are glass or plastic slides that are submerged to various depths for specified colonization periods (usually 2 to 4 weeks). Periphyton usually is most important in shall flowing streams but also is frequently sampled in standing water bodies.

Sampling from natural substrates usually is accomplished by scraping a pre-measured area on a selected substrate with a knife-like object and placing the scraped material into a sample vial. Artificial substrate slides may be scraped in the field or shipped to the analytical laboratory to be processed by a laboratory technician.

SAMPLE CONTAINERIZATION AND PRESERVATION

Scraped periphyton material usually is placed in a 2 to 4 ounce wide-mouth plastic jar one-half full of water and preserved with Lugols or Meyers M-3, at a concentration of about 1 to 2 percent. Whole slides or slide sets are shipped in 8 to 16 ounce side-mouth jars, with sufficient water to cover the slides, and preserved as described above. Shipping, handling, and chain-of-custody procedures are provided in Chapter 7.

SAMPLE REPRESENTATIVENESS

For natural substrates, the samples should be collected from the predominant substrate. However, if a more comprehensive description of the periphyton communities is desired, samples from 3 or 4 of the most abundant substrates should be sampled (e.g., rock, tree branches, debris, tree leaves, etc.). For artificial substrate samples, samplers may be placed at various depths and locations within the photic zone of the water body. For quantitative sampling, at least two replicates should be collected at each sampling location.

SAMPLE AND DATA ANALYSES

Periphyton samples should be analyzed according to standard accepted procedures. Special preparation of slide mounts is required for diatom analyses. Data usually are expressed in terms of numbers of algal species per unit area (e.g., number per cm^2). Biomass determination is also made according to standard accepted procedures. Biomass is expressed in terms of weight per unit area (e.g., mg/cm^2).

Species diversity indices also may be calculated, as well as a variety of other biotic indices. These indices should be calculated using standard, accepted methods in accordance with the project work plan and QA plan.

11.5.3 Zooplankton

Zooplankton are microscopic invertebrate animals, capable of locomotion, consisting mainly of copepods, cladocerans, and rotifers. The type of sampling gear and sampling procedures to be used depend upon study objectives and type of aquatic system being sampled.

Zooplankton populations usually are more important in large slow-moving streams than in small, shallow, and swift streams. For most rivers, and for deep standing water bodies, a pump or water bottle is used to collect at least 100 liters of water, which is then filtered through a No. 25 plankton net (64-µ mesh), or a No. 10 plankton net (153-µ mesh). Water bottles used to collect samples are VanDorn or Kemmerer types, as for phytoplankton sampling.

For shallow, wadeable standing water bodies, pouring water through a No. 25 plankton net with a plastic container usually is the easiest method. When quantitative data are required, the volume of water collected and filtered must be measured.

Qualitative or semi-quantitative zooplankton samples can be collected by casting a weighted plankton net from shore or a boat, allowing it to reach the desired depth, and slowly (0.5 to 1.0 m/s) retrieving it. Methods applicable for standing water also are generally applicable in estuarine and coastal marine systems; however, larger net mesh sizes may be desirable (e.g., No. 6 or No. 10 nets). It also may be necessary to add weight to the sampling equipment to compensate for strong tidal currents.

Conical plankton nets can be used to collect quantitative samples in coastal areas or deep standing water bodies. For quantitative sampling, a flow meter is mounted in the net to measure the volume of water filtered.

SAMPLE CONTAINERIZATIN AND PRESERVATION

Since sample material is concentrated into a sample bucket at the end of a net, 8 ounce plastic jars usually are sufficient to containerize the volume of material collected. The sample is preserved in a 5 percent solution of fomalin in water. Sample handling, shipment and chain-of-custody procedures are described in Chapter 7.

SAMPLE REPRESENTATIVENESS

To ensure representativeness, samples from slow-moving rivers usually are collected from several different habitats or depths (e.g., mid-channel, near-shore, backwater areas, surface and bottom, etc.). For deep lakes, samples usually are taken from discrete depths and from open water (pelagic) and near shore (littoral) areas. In shallow standing water, samples generally are taken from open water and from areas containing emergent or submerged aquatic vegetation. For quantitative sampling, at least two replicates should be collected. As in the case of phytoplankton, light penetration, as well as thermal and chemical (salinity and dissolved oxygen) stratification are factors to consider in the sampling strategy.

SAMPLE AND DATA ANALYSES

Zooplankton samples are analyzed according to standard accepted procedures. Samples are sub-sampled and placed in special counting chambers, which are placed under a dissecting microscope at 10 to 70x magnification for identification and enumeration. Some organisms may require closer examination under a compound microscope to ensure accurate identification.

Data usually are expressed in terms of number per unit volume. Certain biotic/diversity indices may also be calculated, using standard, accepted methods, in accordance with the project work plan and QA plan.

11.5.4 Benthic Macroinvertebrates

Benthic macroinvertebrates (benthos) are invertebrate animals such as worms, crustaceans, and insects that are associated with the substrates of water bodies. Benthos sampling may be conducted to develop information about the benthic community itself, or about tissue contamination, or both. Whenever chemical analysis is to be performed, the analytical laboratory should be consulted to determine sample containerization, preservation, and handling requirements.

As with the previously described communities, samples may be collected quantitatively or qualitatively. Again, the objectives of the study and the type of system to be sampled should dictate the sampling methodologies.

In large, slow-moving rivers or deep lakes, bottom species usually are collected using a Ponar dredge. If river flow is swift, extra weights may be added to the Ponar. The Ekman grab may be used in slower-moving or standing waters with soft substrates.

Artificial substrate samplers are used to monitor changes in benthos using uniform substrates. Artificial substrates usually are multiplate or rock-basket type samplers and require a 4 to 6 week colonization period.

In shallow, fast-moving streams, a Surber sampler or a Hess sampler often is used to obtain a quantitative sample.

For qualitative or semi-quantitative samples from a shallow stream or the banks of river ponds or lakes, a dip net may be used.

For drifting organisms, drift nets usually are placed in the river for a predetermined period of time, which may coincide with diurnal activities of the benthos (i.e., most drift occurs at night).

Benthos sampling for tissue contaminant analysis generally is accomplished using qualitative sampling techniques. For deep lakes and slow-moving rivers, Ekman and Ponar dredges are the best sampling devices. For shallow streams and bank habitats, the best device is a dip net.

SAMPLE CONTAINERIZATION AND PRESERVATION

Sample material from most sampling procedures will fit in 16 ounce wide-mouth plastic jars. Drift samplers usually collect a considerable amount of debris and therefore usually require the use of 1 gallon plastic jars. Artificial substrates usually are scraped in the field, and the colonized material and organisms transferred into 16 oz. Jars. Samples may be preserved with either a 5 to 10 percent final concentration of formalin or a 70 percent final concentration of ispropanol.

For samples collected for tissue contaminant analyses, provision for field sorting must be made. The organisms are sorted from the debris and placed in clean glass or plastic jars. These samples should be shipped immediately on ice, or frozen as soon as possible if immediate shipment is not possible.

Sample handling, shipment and chain-of-custody procedures are described in Chapter 7.

SAMPLE REPRESENTATIVENESS

In large, slow-moving rivers, samples from the bottom usually are taken from various habitats such as mid-channel, nearshore and backwater areas. Usually, three or four grab samples are combined to represent one sample. From shallow, swift streams sampling is concentrated in shallower riffle areas, with three or four replicate samples being collected. Occasionally, samples from pool habitats also are collected. For lakes and ponds, samples usually are collected from littoral and deeper water habitats.

SAMPLE AND DATA ANALYSES

In the laboratory, benthos samples should be analyzed according to standard accepted procedures. For benthos, samples must be picked and sorted prior to identification and enumeration analyses, most of which can be done under a dissecting microscope (7-80x). For most species of worms and midges (Chironomidae); use of a compound microscope also is necessary. Biomass analysis may be required and standard procedures for biomass analysis can be found in Weber 1973 or Standard Methods (APHA 1985).

Data analysis involves presentation of results as numbers of organisms per unit area (e.g., no/ft^2or no./m^2). Drift often is expressed as numbers per unit volume (e.g., no./m^3). Biomass is expressed as weight per unit area (e.g., gm/m^2).

Species diversity and biotic condition indices can be applied to benthos data. The study objectives and work plan/QA plan should be consulted prior to calculating diversity and/or biotic indices.

11.5.5 Ichthyoplankton

Ichthyoplankton are the egg and larval stages of fish. Ichthyoplankton samples usually are collected quantitatively by towing a net at fixed or varying depth and measuring the volume of water that passes through the net during the tow. Either bongo nets or plankton nets may be used, depending on sampling objectives and circumstances. Net sizes usually range from 330 to 505-µ Nitex mesh depending upon the size of organisms expected and objectives of the study.

In flowing water systems where depth and current are adequate, sampling sometimes can be accomplished from a stationary position by orienting the nets to the stream flow. For slow-moving rivers or standing water bodies, the nets have to be towed. Flow meters inside the net are used to determine the volume of water filtered. Usually 50 m^3 must be filtered to obtain an adequate sample.

SAMPLE CONTAINERIZATION AND PRESERVATION

Sample material is placed in 8 to 16 ounce wide-mouth plastic jars and preserved with formalin to a final concentration of 5 percent. Rose-Bengal stain should be added to the samples if considerable vegetative debris is present in the sample. Sample handling, shipment and chain-of-custody procedures are described in Chapter7.

SAMPLE REPRESENTATIVENESS

In large, slow-moving streams, samples generally should be taken from potential fish-rearing and nursery habitats. Other areas may be important to project-specific objectives, and should be designated in the work plan. Samples usually are collected from discrete depths using vertical or oblique tows. A minimum of two replicates per station should be collected for quantitative sampling.

SAMPLE AND DATA ANALYSES

Ichthyoplankton organisms must be picked from collected material and sorted prior to species identification and enumeration. Biomass analyses usually are not required for ichthyoplankton.

Data analysis usually includes calculation of population densities in terms of numbers of organisms per unit volume (e.g., no./m^3).

11.5.6 Fish

Sampling of fish involves active or passive sampling techniques. The technique used depends on the objectives of the study and type of water body sampled. It is difficult to conduct meaningful quantitative fish sampling because of the mobility of fish. Instead, standard population estimating techniques must be used after sampling has occurred. Because of the different size ranges and different habits of fish, use of one method usually is not sufficient to obtain good population estimates for a variety of species.

Fish sampling may be conducted to develop information about the fish populations themselves, or about fish tissue contamination, or both. Sample collection procedures should be tailored to the objectives of the study. Whenever chemical analyses are to be performed, the analytical laboratory must be consulted to determine sample handling and preservation procedures.

Both active and passive techniques can be used in sampling fish from flowing waters. Electrofishing is the most frequently used active technique. Passive techniques include the use of hoop nets, gill nets or trap nets. In wadeable backwater areas, seining is often the method used. Another active technique that can be used in large rivers is trawling, which requires the use of a large boat with sufficient power to tow the trawl.

For large standing water bodies, active techniques such as electrofishing usually are effective only along shorelines; whereas trawling may be used only if the lake is large enough and the bottom is relatively free of debris. For deep lakes, therefore, the most frequently used procedure is gill netting or trammel netting. These nets can be set at different depths and locations depending on the species of interest, and their seasonal movements. For bottom-feeding fish (e.g., catfish), often the best technique for collection is trotlining.

Except for electrofishing, the above techniques for standing water generally can be applied to estuarine and coastal marine environments.

Fish samples usually are processed (i.e., species identification, enumeration, and measurements of length and weight, if required) in the field. Species that cannot be identified in the field are preserved in formalin and returned to the laboratory for identification.

SAMPLE CONTAINERIZATION AND SHIPMENT

Except for unidentified fish and fish collected as voucher fish specimens, fish usually are processed in the field and returned to the water body. For fish to be returned to the laboratory, 32 ounce to 1 gallon size plastic jars are used. These samples are preserved in a 10 to 15 percent formalin solution.

Samples requiring tissue contaminant analysis usually are wrapped whole in aluminum foil, frozen and shipped to the analytical laboratory. Some field dissection may be required, as in the case where a fillet, rather than a whole fish is to be sent to the laboratory.

Sample handling, shipment and chain-of-custody procedures are described in Chapter 7.

SAMPLE REPRESENTATIVENESS

In flowing waters, samples should be taken from as many different habitats as possible. Habitats may include deep water, back waters, undercut blanks, debris jams, etc. Electroshocking in streams usually is performed along the banks, which have a variety of habitats. The sampling transect and duration should include the major habitats represented in the study reach. Life histories (i.e., spawning movements, etc.) of target fish should be considered when selecting sampling techniques. In lakes, sampling may be keyed to seasonal movements of fish.

When collecting fish for tissue contaminant analysis, a target fish or several target fish usually are selected on the basis of study objectives. Target fish usually include top-feeding carnivores (bass, perch, etc.) omnivores (catfish), and bottom-feeders (carp, catfish, suckers).

SAMPLE AND DATA ANALYSES

Fish samples usually are analyzed in the field rather than in the laboratory. Age determinations must be performed in the laboratory on whole fish samples, or using scales or spines removed in the field. Field procedure and data collection, should include determination of length, weight, and overall health and condition of the fish. The objectives of the study will determine the appropriate analyses to conduct.

Data analyses usually include calculation of the number of fish caught per unit of time with each collection procedure used. In some cases population estimates may be developed using standard techniques such as Seber-LaCrene. Species diversity and other biotic indices also may be used.

11.6 Terrestrial Biology Sampling

11.6.1 Vegetation

Sampling techniques for describing or characterizing areas of terrestrial vegetation typically are limited to plant cover biomass estimations and vegetation mapping. Vegetation also may be sampled for contaminant analyses. Vegetation study plans may require floristic voucher collection.

The sampling method used depends upon the growth form or forms to be sampled and the objectives of the study, which should be explained in the QA plan or work plan. When sampling to describe shrub and herb communities, and the amount of cover represented by each, the Line-Intercept and/or Line-Strip method usually is used. Description of shrub and forest communities is best accomplished using the Point-Centered Quarter method which provides information on shrub and tree densities and cover, as well as diameter at breast height (DBH) data for trees. Plant communities containing all three major growth forms may be sampled using the Nested Quadrat method. This method provides density and cover data for the tree stratus, shrub stratus, and herb stratum.

Biomass or vegetation standing crop and net aerial primary productivity may be measured by the Standing Crop Biomass and Net Aerial Primary Productivity method or by the

Caged Exclosures/Single Harvest Method. The Standing Crop Biomass measures the amount of vegetation per unit area at a particular point in time, while net aerial primary productivity (the rate of dry-matter production) is measured by obtaining a series of biomass samples over a certain time period. The Cage Exclosure/Single Harvest method involves the initial removal of enclosed plant material before the growing season and the subsequent removal of vegetation that has grown over a specified length of time. This procedure also provides information on plant growth rates.

Vegetation studies often require detailed vegetation mapping for purposes of project planning or habitat evaluation. Vegetation mapping requires the use of infrared or color aerial photographs of the area to be mapped, as well as ground truthing. This information is initially transferred to a draft vegetation map. This map is then ground-truthed prior to being finalized.

When plant tissue samples are to undergo chemical analysis, special procedures must be employed in sample collection, containerization and handling. To some extent these will depend on the specific analyses required, and should be addressed in the project QA Plan.

SAMPLE CONTAINERIZATION, PRESERVATION AND HANDLING

Vegetation voucher specimens are to be shipped or transported to the herbarium according to their specific specifications. Samples for biomass determination usually are placed in plastic bags, labeled and transported to the laboratory in coolers. Plant samples collected for tissue contaminant analyses are doubled or tripled, wrapped in decontaminated or clean aluminum foil, labeled, and placed in coolers for shipment to the analytical laboratory. Samples should be shipped under the chain-of-custody procedures described in Chapter 7 of this manual.

SAMPLE REPRESENTATIVES

Sampling plots for vegetation descriptions and data collection are selected such that all major vegetation types are included. This usually is done in the office by studying vegetation maps, if available, or aerial photos of the area of concern. The number of transects chosen must be sufficient to provide a complete representation of the study area.

DATA ANALYSES

Field data collected on standardized forms can be analyzed in several ways, therefore, data analysis will depend upon the project objectives. Line-intercept procedures provide identification of species and assessment of ground cover provided by each. Total ground cover is expressed as a percentage. Biomass measurements usually are expressed in terms of pounds per acre or grams per square meter by species as well as total biomass for the entire sampling area. Productivity may be expressed as weight per area per time (e.g., gm per acre per month).

11.6.2 Characterization of Fauna Populations

The terrestrial fauna sampling techniques discussed in this section are limited to the following: small mammals, big game, predators, avifuna (passerine and passerine-like birds, gamebirds, and raptors). These sampling procedures provide methods for population characterization rather than actual sample collection. Collection of terrestrial fauna for contaminant analyses is discussed in a Section 11.6.3. Each of the following procedures must be supplemented with the field documentation procedures described in Section 10.6.

Small Mammals - Small mammals usually include members of the rodent families (mice, rats, squirrels, etc.) as well as rabbits and hares. Sampling methodologies should correspond to the objectives in the study plan. If semi-quantitative population and species presence information is required, snap trapping or live trapping along a sampling line should be used. However, if more precise population density information is required, sampling by live trapping and mark and recapture techniques should be used. When using live trapping techniques (Sherman live traps), use of bait is required to lure the animals into the traps. Rabbits and hares usually are censused using night-time spot-lighting techniques. Trapping can be done but it is difficult to achieve a representative population sample.

Mammalian Predators - Mammalian predator populations include families of carnivores such as coyotes, wolves, mountain lions, bears, and mustelids (skunks, badgers, mink, etc.). Sampling of these populations is accomplished by the Scent-Station Visitation Survey method. Basically, this method requires the use of a scent attractant, such as a rotten egg smell, placed in an area that has been cleared of vegetation and the ground smoothed over. Foortprints of the animals visiting the scent station are identified and counted after a specified period of time (e.g., one night to several days).

Large Mammals - Large mammals are animals that belong to the order Artiodactyla and include deer, elk, antelope, big-horned sheep, mountain goats, and buffalo. Censusing of these animals usually is accomplished by aerial surveys or by pellet group counting surveys. Aerial surveys require the use of single-engine, high-wing aircraft or helicopter; and therefore, good office planning prior to field work is essential. For pellet group counting, sites must be selected in habitat expected to be used by large mammals of concern. Accurate estimation by this method may require several surveys of the same transect over a year's time.

Avifauna - For sampling of passerine birds (sparrows, robins, etc.) and passerine-like birds (woodpeckers, hummingbirds and doves), the most common methods are the Emlen Avian Strip Transects method and the Avian Road Count method. These methods require an avian biologist capable of identifying most birds. The Emlen method involves replicate surveys along predefined transects. For the road count method, roads that cut through desired habitats or within the proximity of the project site are used as transects.

Upland gamebirds usually are counted using an auditory count method in which an experience avian biologist makes a certain number of stops along predefined transects, and listens and records the number of territorial male birds heard during a specified time period. For upland gamebirds with special mating requirements (e.g., sage grouse), the Aerial Censusing of Upland Gamebird Lek Activity is used. This aerial method also may be used to obtain an aerial population estimate for sage grouse or prairie chickens. Since this method requires the use of aircraft, pre-planning is important. This auditory bird count method is a ground method used for birds that are breeding.

Waterfowl censusing techniques are based on the fact that these birds are generally in a confined area (i.e., around a pond, on a river, etc.). The usual method, therefore, is to simply count birds from a protected vantage point. Waterfowl may also be counted by the aerial transect methods used for big game.

Raptors (eagles, hawks, and owls) are sampled by both aerial and ground techniques. As described for large mammal aerial surveys, an airplane or helicopter is required for aerial raptor surveys. Pre-flight planning as to the location flight transects is very important. Topographic maps with project site boundaries should be review prior to conducting the aerial surveys.

For raptor nest surveys, areas of potential nest sites are examined on project area maps and sampling transects are determined. The field observer then uses binoculars and spotting scopes to examine the levels of activities at the nests.

REPRESENTATIVENESS

Passerine and passerine-like birds are highly mobile and many are migratory. Therefore, censusing strategy must take into account bird life histories as well as preferred habitats. Sampling transects for raptors usually are systematically selected in habitats where raptors are expected to be found.

Upland gamebirds usually are censused during the breeding season and sampling is focused on nesting habitats. Waterfowl sampling normally should be conducted at several types of wetland habitats (if present), such as along a river, pond, lake, or estuary.

DATA ANALYSES

Aerial survey data provide an actual large mammal population estimate for the area sampled. This information can then be extrapolated to provide a population estimate for larger areas by multiplying the number of large mammals (by species and total) times the number of unit areas (acres, square mile, etc.) of similar habitat. For the pellet group method, the result is expressed in animal use days/acre.

Data analyses for the Emlen variable strip method includes the estimation of population size of the passerine birds in the area. A species list of birds also may be prepared. For upland gamebirds, auditory methods as well as aerial counts provide an estimate of the population of birds using the area. Procedures and calculations used are too variable to discuss in this manual and therefore are determined by the discipline manager with approval from the project manager, and are described in the project work plan/QA Plan.

For raptors, data are reduced from the aerial data survey sheets into a tabular format for the final report. Data for aerial surveys may be reported as number of raptors per unit area. Nest survey data are reported as numbers of active or inactive nests in or near the project area.

11.6.3 Fauna Sampling for Tissue Contaminant Analysis

This section describes basic procedures for the collection of the terrestrial fauna discussed in Section 11.6.2 for tissue contaminant analyses. For small mammals, snap trapping or live trapping can be used. For medium-size carnivores, live trapping or use of approved firearms (collector must obtain a hunting license) can be used to collect specimens. For large mammals, hunting with a license usually is the only practical procedure. Avifauna sampling also can be accomplished by hunting for the appropriate birds. Hunting for raptors is likely not an option in most states, due to strict regulations protecting those species. Therefore, the cooperation of state fish and game departments is essential. If passerine birds are desired, mist netting is a procedure often use. Prior to field collection, standard field procedures should be written as part of the overall work plan.

SAMPLE CONTAINERIZATION, PRESERVATION, AND HANDLING

For each of the above faunal types, collected samples should be processed as soon as possible. Small mammal samples generally are placed in plastic bags or wrapped in aluminum foil and shipped to the analytical laboratory as soon as possible. If possible, all samples should be frozen prior to shipment to the laboratory.

In some cases, only selective tissues are of interest. This may require field dissection and extra care must be taken to avoid sample contamination. Dissections also may be accomplished in the analytical laboratory. For medium-sized animals and predators, and large mammals, field issue dissection is almost always required. Appropriate dissection and sample containers must be described in the project work plan or QA plan. For passerine birds caught in mist nets, the procedures used for small mammals generally apply.

Samples must be shipped under the chain-of-custody procedures described in Chapter 7.

SAMPLE REPRESENTATIVENESS

Terrestrial fauna samples for tissue contaminant analyses should be collected in areas where exposure is expected as well as from control (unaffected) areas. If the target animals are highly mobile, a different, unaffected region of a state may be required for sample collection. Non-migratory birds are the best species to select for tissue contaminant analyses for avifauna.

11.7 Ambient Air Sampling

11.7.1 Particulate Measurements

Particulate measurements usually involve collection of airborne particulate matter on a pre-weighed glass fiber filter using a high-volume air sampler (HI-VOL). The exposed filters are then re-weighed to determine the mass of collected airborne particulate matter. Procedures for the gravimetric analyses should follow standard accepted methods. Ambient concentration is determined as the mass of collected particulate matter divided by the volume of air sampled. The air volume sampled is determined from flow rate measurements and the duration of the sampling period. This process involves two basic sets of measurements that must be NBS-traceable - the mass and the sample volume. Determination of the sample volume alone requires measurements of time, temperature and pressure, each of which should be traceable.

Size-selective attachments are available for HI-VOLS, to permit the collection of only inhalable particulate matter. By the currently accepted definition, inhalable particulates are particles with an aerodynamic diameter of less than ten microns. Use of a size-selective inlet attachment has no significant effect on the calibration and sample collection procedures.

The filter media and HI-VOL samplers used for this procedure are commercially available. Particulate samples collected by this method may be chemically analyzed (after gravimetric analysis) for a variety of organic and/or inorganic constituents. There are, however, many limitations to the use of this method for measuring airborne chemical contaminants. For example, the sample collection period is typically 8-12 hours, during which the sample is exposed to a large volume of ambient air. Only non-volatile, solid substances are collected efficiently by the filter media. Further significant time elapses between sample collection and completion of gravimetric analysis (at least 24-36 hours), during which samples must be equilibrated in a temperature-and -humidity-controlled environment, and it is not possible to seal in volatile constituents or prevent chemical reactions during this time. Therefore, the method does not lend itself to the measurement of volatile, semi-volatile or potentially reactive air contaminants, but only to those constituents that are chemically stable and firmly absorbed onto the airborne particulates. It is virtually impossible to obtain real-time, on-site air quality assessments using this method.

As with all sampling, careful documentation of sample collection, analysis and chain-of-custody is necessary.

11.7.2 Sampling for Organics Using Solid Sorbents

Ambient air concentrations of volatile or semi-volatile organic constituents can be determined by drawing ambient air through cartridges of sorbent materials such as Tenax®, XAD-2 resin, activated charcoal, polyurethane foam (PUF); or into a summa canister; and then desorption and analysis of the collected contaminants in the laboratory. The sample collection procedure is similar to particulate sampling, in that the volume of air sampled is determined through measurements of flow rate and sample duration, and sample duration is typically several hours. However, much smaller sample volumes are required, necessitating much more precise flow rate measurements.

Commercially available sorbent cartridges usually consist of a column of sorbent material bound on either end by glass wool plugs and sealed in a glass tube. Tenax® tends to break down, producing degradation products such as toluene, and therefore must be thoroughly desorbed before use. For this reason, Tenax® cartridges may be assembled in the laboratory, rather than being purchased intact.

Sorbent cartridges must be stored in protective air-tight containers prior to use and during shipment to the laboratory. Labels and ink markings must not be placed on the cartridges themselves, and handling of the cartridges must be kept to a minimum and done only with clean gloves and/or Teflon-tipped tongs. The cartridges should also be protected from exposure to light, by wrapping with aluminum foil or other opaque material. Sorbent cartridges should be stored at 4°C and analyzed as soon as possible after exposure.

For smaller sample volume applications (e.g., Tenax®), the apparatus used for drawing sample air through the sorbent cartridge usually consists of a commercially available, rechargeable battery-powered personal sampling pump. The pump must be capable of providing the desired flow rate for an extended period of time (8-12 hours), without interruption or abrupt flow rate variations. Programmable flow-controlled pumps are available, but are expensive. Adjustable pumps with built-in pneumatic flow control mechanisms are typically used. These provide suitable flow rates with adequate control, but flow rate measurements at the beginning and end of each sample are required. The volume, time, temperature and pressure standards used for these flow rate measurements and calibrations must be traceable to NBS or equivalent authoritative standards. Calibration procedures for personal sampling pumps are provided by the manufacturer.

For large sample volume applications (e.g., PUF) a sampling device similar to a HI-VOL is used.

Sample collections with sorbents requires careful planning. Much effort can be wasted in collecting samples that are invalid either because the sorbent is saturated with one or more of the constituents, or because the quantities of captured constituents are less than the detection limit. Sample volume must be carefully considered on the basis of the nature and expected ambient concentrations of the contaminants to be captured. it is sometimes necessary to conduct a preliminary qualitative sampling round in order to obtain enough data to plan a successful quantitative sampling effort.

11.8 Asbestos Sampling

There are two basic forms of asbestos sampling. Bulk sampling is the direct sampling of material, such as insulation, that is suspected to contain asbestos. Air sampling involves the filtration of a measured volume of air with a specially designed filter cartridge.

Bulk sampling is performed to determine whether building materials contain asbestos and how asbestos-containing materials (ACM) are distributed in a particular facility. It usually is performed in conjunction with a detailed asbestos survey, which must be conducted by a trained and experienced asbestos professional. Bulk sampling procedures are provided by established _____.

Air sampling may be performed to detect the presence of friable asbestos, to monitor work zone levels during an asbestos abatement project, or to verify that an area is suitable for rehabitation following an abatement project. Air sampling procedures are established by ___________ and the equipment calibration procedures are established by the equipment manufacturer.

12. GUIDELINES FOR PLANNING SAMPLE ANALYSES

12.1 Purpose and General Provisions

Many alternatives are available for chemical, biological and toxicological analyses, and selection of the appropriate alternative is critical to both the technical success and cost-effectiveness of a study. Selection of the most appropriate analytical approach is a complex process, involving factors that may vary substantially from one project to another. Awareness of these factors is essential, and requires a thorough understanding of the analytical procedures, the chemical, biological, and physical nature of the environment being examined, and the objectives of the study. it is therefore important that the analytical strategy for each project be planned through a collaborative effort among the scientists, engineers and laboratories participating in the study.

12.2 Responsibilities

12.2.1 It is the responsibility of the project manager to establish the informational objectives of the investigation, through discussions with the client and to plan the analytical strategy, through consultation with the analytical task manager other members of the project team.

12.2.2 The analytical task manager is responsible for advising the project manager as to the analytical alternatives available and their advantages and disadvantages, and for recommending the most technically and fiscally advantageous approach.

The analytical task manager is also responsible for advising the sampling team and quality assurance officer on the appropriate sample collection and handling procedures.

12.2.3 The Quality Assurance Officer and/or Quality Control Officer are responsible for defining the sampling and analytical quality control program, through consultation with the analytical task manager, and for incorporating it into the project quality assurance plan (See Chapter 3).

12.3 Method Selection

References to standard analytical methods for commonly needed tests are given in Appendix B of this Quality Assurance Manual. These references may be used to identify the basic procedures needed for a project, but the Analytical Services QA Officer and the laboratory should be consulted to adapt the standard procedures to each specific project.

13. QUALITY CONTROL FOR FIELD MEASUREMENT INSTRUMENTS

13.1 Purpose and General Provisions

Chapters 10 and 11 of this manual deal with the collection of samples for laboratory analysis. In those activities, the actual measurements are made in the laboratory. Environmental consulting and engineering projects often involve measurements that must be made directly in the field-for example, real-time air monitoring, field screening of soil samples, and pH, conductivity and temperature measurements for water samples. The scope of field measurement efforts may range from simple, periodic measurements that play a supporting role in some larger measurement effort to large-scale, multi-year continuous ambient air monitoring programs. Regardless of the scope, these endeavors involve the use of instrumentation that must be calibrated and in good working condition in order to fulfill the quality objectives of the measurement program.

Quality Assurance plans for studies that involve field measurements must provide a quality control program for those instruments that is commensurate with their role. This chapter provides general guidelines for control of field measurement equipment, and for the development of quality control programs for field measurements. Specific procedures for operation, maintenance and calibration are found in the manufacturer's instructions for each field measurement instrument. Quality Assurance and Quality Control programs for criteria pollutant ambient air monitoring and associated meteorological monitoring projects are modeled after the USEPA's "Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)" (EPA-450/4-87-007, May 1987), "On-Site Meteorological Program Guidance for Regulatory Modeling Applications" (EPA-450/4-87-013, June 1987) and relevant portions of 40 CFR 58.

13.2 Responsibilities

13.2.1 The project manager is responsible for determining what field measurements are to be performed and for defining the role of those measurements in the project. The project manager should consult with the Health and Safety Officer and the Quality Assurance Officer to determine what field measurements will be required for Health and Safety or Quality Assurance purposes. The project manager should also consult with the appropriate equipment manager regarding the availability of the required measurement equipment.

13.2.2 The Quality Assurance Officer and/or the Technical Director are responsible for designing quality control programs for field measurements and incorporating those measures into the project Quality Assurance plan.

13.2.3 Personnel performing field measurements are responsible for performing the measurements and maintaining and calibrating the equipment in accordance with SECOR SOPs and the project Quality Assurance plan, and for accurately completing the attendant documentation.

13.2.4 Each PIC or Office Manager will assign an Equipment Manager to be responsible for maintaining, issuing and tracking field measurement equipment in accordance with this chapter and relevant SECOR SOPs.

13.3 Equipment Tracking and Preventive Maintenance

All field measurement equipment is maintained under a tracking and preventive maintenance program. The purpose of this program is to:

- Minimize equipment downtown;
- Limit the use of the equipment to qualified, trained personnel;
- Ensure the issuance of complete, functional equipment;
- Ensure the availability of appropriate calibration standards and other ancillary equipment; and
- Facilitate the planning of equipment use and the anticipation of equipment needs.

The storage, preventive maintenance, issuing and tracking of equipment are the responsibility of the equipment manager. He or she performs the tasks described below.

- Storage of Equipment - Field measurement equipment is kept in a designated, limited - access storage area. The equipment manager controls access to the storage area.
- Issuing Equipment - Field measurement equipment is issued only by the equipment manager (or their designee), in accordance with the provisions of this chapter.
- Preventive Maintenance and Repair - Each piece of field measurement equipment undergoes preventive maintenance in accordance with the manufacturer's recommended schedule and procedures. Equipment that is overdue for scheduled maintenance, or that is in need of repair, is not issued for use on a project.
- Record keeping and Tracking - The equipment manager keeps records of routine preventive maintenance, repairs and utilization of field measurement equipment in a bound logbook. Each time a piece of measurement equipment is repaired, or routine maintenance is performed, an entry is made in the logbook, giving the date, nature of repair or maintenance, identification (description and serial number) of the equipment and the initials of the person performing the repairs or maintenance work.
- When a piece of measurement equipment is sent to a vendor for repairs or maintenance, a log entry is made giving the date, name of vendor, identification of the equipment, description of repairs or services required, and initials of the person sending the equipment. When the

equipment is returned, a similar entry is made to document the return. Repair or maintenance by an outside vendor is a service that must be procured in accordance returned equipment.

When measurement equipment is issued to a project, an entry is made giving the date, project number, location of work, identification of the equipment, initials of the person issuing the equipment and the identity of the person to whom the equipment is issued. When the equipment is returned, a similar entry is made, noting date of return, and condition of the returned equipment.

Through the use of the logbook, the equipment manager maintains a continuous written record of the status and the location of each piece of field measurement equipment.

13.4 Portable Equipment

Field measurement equipment can be grouped into two basic categories. Field-stationed continuous monitoring equipment is discussed in Section 13.5. Portable analytical instruments (e.g., pH meters, organic vapor analyzers, etc.) require considerable preventive and corrective maintenance, as well as frequent and careful calibration. Calibrations must be performed in strict accordance with the appropriate SECOR SOP and/or manufacturer's instructions. All portable equipment should be calibration-checked and thoroughly inspected immediately upon its return from each excursion to the field.

13.4.1 Instruments and Applications

COMBUSTIBLE GAS METERS

Combustible gas or vapor levels can be monitored through the use of a portable combustible gas meter, or explosimeter. These devices either manually or mechanically pump a continuous stream of sample air through a chamber that houses a catalyst-coated combustion filament or wire coil. Combustible gases present in the air stream are catalytically burned in the chamber, increasing the temperature of the filament or wire coil and consequently increasing its electrical resistance, which is monitored by an ohmmeter. The ohmmeter display is marked in units of percent of lower explosive limit (LEL) or concentration units (e.g., ppm), rather than ohms. The LEL of a particular flammable gas or vapor is defined as the lowest concentration of that gas or vapor in air that can sustain combustion. The upper explosive limit (UEL) of a particular gas or vapor is that concentration above which combustion cannot be sustained.

Combustible gas meters are not as sensitive as the PIDs and FIDs described below (detection limits approximately 5% of LEL), but they are useful in Underground Storage Tank (UST) investigations and other applications where combustible gases or vapors may be present in high concentrations.

Before the meter is issued for use, the battery should be checked. These meters always should be operated and maintained in accordance with the manufacturer's recommendations and by personnel who have been trained and are proficient in the use of the meters.

The following conditions should be avoided in order to obtain accurate readings and to maximize the combustible gas meter's effectiveness and longevity:

- Operation in temperature outside the range recommended by the manufacturer.

- Operation in environments where leaded gasoline vapors (tetraethyl lead), sulfur compounds (mercaptans, H_2S) or silicone compounds are present. These compounds may attack the catalytic sensor, reducing the meter's sensitivity.

- Sampling of oxygen-deficient atmospheres containing approximately 12% oxygen or less, since the lack of oxygen will affect the combustion of the sample and will result in low meter readings (i.e., under estimation of flammability).

PORTABLE FLAME IONIZATION DETECTORS

A flame ionization detector (FID) pumps a constant stream of air through a chamber containing a hydrogen flame. Most organic vapors are ionized in the hydrogen flame, and the resulting ions are attracted to polarized electrodes in the chamber, producing a current proportional to the quantity of ions and the magnitudes of their charges. For a single organic compound, the response of the detector is a function of the concentration of the compound and its ionization potential. For a mixture of compounds, accurate interpretation of the response as a true concentration is virtually impossible, because the instrument's sensitivity varies from compound to compound. Some models can be converted to perform chromatograph separation of species. This greatly increases the measurement capability of the device, but also complicates the calibration procedure and increases the skill required of the user.

The FID requires a supply of ultra-high purity hydrogen which must be replenished periodically. Most portable units (e.g., the Foxboro OVA) have built-in rechargeable hydrogen cylinders. Although this makes the units more portable, the need for hydrogen constitutes a safety hazard and places an additional burden on the user.

FIDs generally have good sensitivity for straight-chain hydrocarbons and chlorinated solvents. However, they also respond to methane, which may produce false positives if natural methane sources are present. FIDs can be quite sensitive, having detection limits as low as 0.1 ppm for methane, and in the vicinity of 1.0 ppm for most ionized compounds.

Further instructions and information pertaining to the FID are given in the manual supplied by the manufacturer.

PORTABLE PHOTIONIZATION DETECTORS

A photoionization detector (PID) pumps a constant stream of air through a chamber containing an ultraviolet lamp. It operates in much the same manner as a FID, but the ionizing energy is the ultraviolet light, rather than a hydrogen flame. Thus, the burden of hydrogen is eliminated. In the PID, a given molecule will be ionized if the ionization potential of that molecule is within the range of light energy generated by the detector's light source. The light source in the detector is designed to be energetic enough to ionize most trace organics without ionizing the air itself (N_2, CO_2, O_2, H_20). As in the FID, the ions generated are attracted to electrodes within the detector chamber, producing a current proportional to the quantity of ions and the magnitude of their charges. For a single compound, the PID can be calibrated to give an output signal directly proportional to the concentration of that compound in air. For a mixture of compounds with different PID response factors, it is virtually impossible to interpret the PID reading as a true concentration. Thus, in most applications, the PID is useful only as an indicator rather than a measurement device.

Generally, PIDs are most sensitive to aromatics, and will not respond to methane. Manufacturer's instruction manuals provide ionization potentials and instrument sensitivities for specific compounds. Detection limits for most ionized species range from 0.1 - 1.0 ppm. Portable PIDs typically encountered include the HNu and the Photovac "TIP".

Further instructions and information pertaining to the PID are given in the manual supplied by the manufacturer.

PORTABLE GAS CHROMATOGRAPHS

PIDs and FIDs can become portable gas chromatographs with the addition of chromatographic columns and strip chart recorders. The Foxboro OVA can be used with a column, and Photovac makes a series of portable chromatographs with photoionization detectors.

Although the most sophisticated of the Photovac units have some column temperature control capability, most portable chromatographs use ambient temperature columns. Therefore, they must be used in temperature-controlled environments to obtain sufficient repeatability in retention times to permit identification of sample constituents.

Proper operation of portable gas chromatographs requires a higher level of training and experience than the detectors alone. Calibration procedures not only must provide the relationships between peak area and concentration required to quantify individual constituents, but also must provide column retention time windows for a variety of compounds to permit their identification.

13.4.2 Calibration Methods

Calibration methods for typical portable measurement instrumentation are outlined in Table 13-1.

The SECOR SOPs listed in Table 13-1 give detailed instructions for calibration of the corresponding instruments.

13.4.3 Calibration Frequency

Portable measurement instrument should be calibrated:

- Before each use
- After any repair or maintenance

Calibration checks should be performed each day the instrument is used.

13.4.4 Documentation

Each time a portable measurement instrument is calibrated or calibration-checked in the field an entry should be made in the field notebook giving the date, time and results of the calibration or check. In addition, the calibration data sheet provided in the SECOR SOP should be completely filled out.

If a calibration data sheet is unavailable, the following information must be included in the field notebook entry:

- Date;
- Time;
- Instrument type and serial number;
- Identification of calibration standard;
- True value (concentration, pH, etc.) of calibration standard;
- Response of instrument before repair or adjustment;
- Response of instrument after repair or adjustment; and
- Signature of person performing the calibration.

TABLE 13-1
FIELD MEASUREMENT EQUIPMENT CALIBRATION

Device	Calibration	Routine Check Method	Routine Check Frequency	Relevant SECOR SOP
pH Meter	**Standardize in two or more standard buffer solutions**	**Calibration check-analyze standard buffer solution** **Analyze replicates**	**1/10 Samples** **1/10 Samples**	
Conductivity Meter	**Standardized using two or more KCL solutions**	**Calibration check-analyze standard KCL solution** **Analyze replicates**	**1/10 Samples** **1/10 Samples**	
Hydrolab	**Standardize pH and conductivity functions as described above for separate meters**	**Calibration check-analyze standard buffer solutions and KCL solution**	**1/10 Samples**	
Photoionization Detector (HNu)	**Calibrate by sampling clean air and a gas standard containing known concentration(s) of representative species**	**Resample calibration standard**	**Daily**	
Flame Ionization Detector (OVA) (Scanning mode)	**Calibrate by sampling clean air and gas standard containing known concentration(s) of methane and/or other hydrocarbon gases**	**Resample calibration standard**	**Daily**	
Gas Chromatograph	**Calibrate column retention times and detector response factors with standard calibrant mixture**	**Resample calibration standard**	**At least every 2 hours**	

13.5 Automated Continuous Monitoring Instruments

Automated continuous monitors are used for long-term ambient air monitoring programs, usually for criteria pollutants (SO_2, NO_2, O_3, CO). For these programs, the USEPA has provided detailed guidance on quality assurance and quality control. This guidance is listed in Table 13-2. SECOR Standard Operating Procedures (listed in Appendix C) and quality assurance plans for these programs are based on the EPA guidance. This section outlines the major QA program elements for these projects.

13.5.1 Instrument Selection and Configuration

Instruments are selected from the EPA's list of reference and equivalent methods. In addition to the monitoring instruments themselves, these programs require data collection and processing equipment to manage the large quantities of data collected. This equipment and the ultimate configuration of the data management system must provide data in the appropriate format, and must allow for data validation and editing.

13.5.2 Probe Siting

Monitoring sites and sample probes must be located away from obstacles to air flow, local emission sources and potential scavenging influences such as trees. The EPA guidance listed in Table 13-2 contains detailed siting criteria which are used to locate SECOR monitoring sites.

13.5.3 Calibration Control

Calibration of continuous air quality monitors is governed by SECOR SOP ________. Each instrument is calibrated at start-up, and is calibration-checked at least once every two weeks. Recalibration is required whenever a calibration check indicates a bias of greater than ±10%.

13.5.4 Preventive Maintenance

Each instrument type (i.e., manufacturer and model) requires certain routine maintenance to prevent malfunctions and maximize valid data capture. Routine maintenance procedures given in SECOR SOPs are based on manufacturer's recommendations and SECOR experience.

TABLE 13-2
SELECTED EPA GUIDANCE FOR AMBIENT AIR MONITORING PROGRAMS

Title	Document Number
Quality Assurance Handbook for Air Pollution Measurement Systems - Volume I, General Principles - Volume II, Ambient Air - Volume III, Stationary Source - Volume IV, Meteorological	 EPA-600/9-76-005 EPA-600/4-27-077a EPA-600/4-27-077b EPA-600/4-82-060
Ambient Monitoring Guidelines for Prevention of Significant Deterioration	**EPA-450/4-87-007**
On-Site Meteorological Program Guidance for Regulatory Modeling Applications	**EPA-450/4-87-013**
List of Designated Reference and Equivalent Methods	**NA**

13.5.5 Quality Assessment Procedures

EPA quality assurance requirements for ambient air monitoring data include routine procedures to assess and report the precision and accuracy of the data. SECOR procedures for precision and accuracy assessment fulfill these requirements.

PRECISION

Each continuous monitor is challenged at least once every two weeks with a test atmosphere containing a known pollutant concentration in accordance with SECOR SOP ________. The percent difference between the instrument response and the known value is determined for each precision check. At the end of each calendar quarter of monitoring, the mean and standard deviation of precision check percent differences are computed. Further details on procedures and reporting requirements are given in SECOR SOP __________.

ACCURACY

At least once during each calendar quarter of monitoring, a performance audit is conducted in accordance with SECOR SOP __________. The standards used to generate test atmospheres for the performance audit are independent from those used to calibrate the instruments; and the audit is performed by an individual who is uninvolved in the routine operation and calibration of the instruments. The results of each performance audit are forwarded to the Air Quality Lab in Ft. Collins, CO, where they are processed and reported. Corrective action requests are generated if audit results indicate that instruments require recalibration, repair or maintenance. Accuracy reporting requirements are given in SECOR SOP ____________.

13.5.6 Data Validation

Ambient air quality and meteorological monitoring data are reviewed routinely and validated according to SECOR SOP ________, to ensure consistent data quality.

14. PRECISION AND ACCURACY

14.1 Purpose and General Provisions

The complexity of the data interpretation required for a given project may range from the derivation of a simple positive or negative results (contamination is or is not present) to a detailed analysis of the temporal and spacial distribution of the measured variables. Even in the simplest cases, the interpreting analyst must have some knowledge of the quality of the data - its accuracy and precision - in order to distinguish data patterns caused by patterns in the studied environment from those attributable to measurement error as a factor in data interpretation varies with the complexity of the data interpretation objectives. It is therefore inappropriate to impose a stringently standard data assessment procedure on all studies. The data quality goals for each project should be stated in the project quality assurance plan, along with the procedures by which the actual quality of the data will be measured. Whatever data assessment procedures are used, it is important to remember that the meaning of the resulting precision and accuracy data is intimately tied to the procedures by which it was estimated. The exact procedures used always must be documented.

The purpose of this chapter is to provide some statistical tools that can be used with information obtained from quality assurance samples (Chapter 10) to estimate precision and accuracy. This chapter does not provide specific precision and accuracy assessment procedures for criteria pollutant ambient air monitoring data; those procedures are governed by Chapter 12 and the appropriate SECOR SOPs.

14.2 Responsibilities

14.2.1 It is the responsibility of the project manager to be cognizant of data interpretation objectives and their attendant data quality requirements in planning and budgeting the study.

14.2.2 It is the Quality Assurance Officers responsibility, through the Quality Control Officers, to advise the Project manager on the data quality goals and assessment procedures appropriate for the project, and to incorporate mutually acceptable procedures into the Project QA Plan.

14.2.3 It is the responsibility of the person performing the interpretive analysis of data to determine and take into account the data precision and accuracy according to the guidelines provided in the Project QA Plan and this chapter.

It is also this person's responsibility to notify the project manager and Quality Assurance Officer in the event that the planned data assessment procedures prove unworkable, and to document the revised procedures in the project-task file and in the report.

14.3 Definitions

X_i = the i^{th} replicate measurement

T = the true value of the quantity being measured (as in a spiked sample)

$\overline{X}$ = the average of Xi

$$\overline{X} = (X_1 + X_2 + - - - +) / n \quad (1)$$

B = the sample bias

$$B = X - T \quad (2)$$

S = the sample standard deviation

$$S = [\, \Sigma\ (X_i - \overline{X}\ )^2 / (n - 1)\,]^{1/2} \quad (3)$$

CV = the coefficient of variation

$$CV = 100\ S / \overline{X} \quad (5)$$

R = the sample range - the difference between duplicate measurement results

R% = the relative range

$$R\% = 100\ R / \overline{X} \quad (6)$$

Replicate - Repeated measurements of the same quantity. For the purpose of this chapter, replicate means more than one repetition, as opposed to duplicate.

Duplicate - Two measurements of the same quantity

14.4 Measurement Error and Variability

Consider two ground water samples taken from two monitoring wells on opposite sides (up-gradient and down-dradient) of a suspected contaminant source. If the analytical results for the down-gradient sample indicate higher contanimant levels than those of the up-gradient sample, then it might seem logical to conclude that the down-gradient ground water has contamination not present in the up-gradient ground water, and that the additinal contaminatin was contributed by the suspected source. Without further information, however, one cannot be very confident in that conclusion, because there are three possible contributors to the difference between the two samples:

1) A real difference in ground water contaminant levels between the two wells.

2) Analytical error,

3) Measurement error introduced in the collection, containerization, handling, shipment, and storage of the sample.

In every iteration of the sample collection and analysis process, some error is introduced by the second and third source, no matter how experienced and skilled the sampler and analyst.

Returning to the example, let us suppose that the analytical laboratory performed duplicate analyses of the down-gradient sample (DG). That is, they took two aliquots out of the sample container, subjected both to the full preparation and analysis procedure, obtained two analytical results and averaged them to obtain the reported result. These duplicate results would provide a measure of the variability of the analytical method, and would permit the investigator to see how much of the difference between DG and the up-gradient sample (UG) might have been contributed by analytical error. Clearly, as the difference between the duplicate results approaches the magnitude of the difference between DG and UG, the conclusion that the down-gradient ground water is more contaminated than the up-gradient water grows dubious.

But the third source of error, the collection and handling of the samples, still has not been addressed. This error contribution can be estimated through the collection and analysis of field duplicates or replicates. Variability among analytical results for field duplicates or replicates is contributed by both analytical error and the collection and handling of samples, but not by real variations in the sampled population (in this case, the aquifer). Therefore, as the variability among field duplicates or replicates approaches the magnitude of the difference between UG and DG, the likelihood that any real difference has been observed between up-gradient and down-gradient concentrations grows smaller.

Since the conclusions drawn from environmental investigation data can have costly consequences, it is prudent to consider the quality of the data, especially in terms of its accuracy and precision. The following sections provide some statistical tools to be used in determining the accuracy and precision of data.

14.5 Estimating the Precision of Data

Precision is a measure of the degree of variability in the error of measurements. It is usually estimated from the results of repeated attempts to measure the same quantity by the same method. If the individual results of these replicate measurements agree closely with one another, they indicate good precision. Conversely, large variations among replicate results indicate poor precision. The statistic most often used to represent precision is the sample standard deviation (S). There are many uses of the standard deviation statistic, but this discussion deals with estimation of the measurement variability contributed by error sources, and therefore is limited to the computation of the standard deviation among replicate measurements.

The sample standard deviation is an estimate of the population standard deviation, which cannot be known without including the entire population in the statistical sample. The greater the sample size, the better estimate of population standard deviation is provided by S. Therefore, one can improve one's estimate of data precision by increasing the number of replicate samples. However, budgetary constraints and other practical considerations usually limit the number of replicates to about one per twenty samples (see Section 10.5). In relatively small-scale studies, this typically means that for each type of sample and for each analysis, there will only be one field duplicate. In larger-scale studies, such as on-going air or ground water monitoring programs, many field duplicates or replicates are collected and analyzed, and better estimates of precision are achievable. Precision assessment methods are given below for both situations.

When no field duplicates or replicates are available, laboratory replicate analyses may be substituted in the procedures below, but the results be the precision of the analytical procedures and will not represent error contributions from sample collection and handling.

14.5.1 One Field Duplicate

When only one field duplicate has been collected and analyzed, only a gross approximation of standard deviation may be obtained, but the effort is not fruitless. The variability present in the analytical results for one field duplicate pair provides an indication of how large a difference between any two samples can be attributed to measurement error, rather than to real variations in the sampled population.

In the case of one field duplicate pair, the range, or the difference between the two analytical results, provides as good an estimate of the standard deviation as equation 3 (Section 14.3). The range (R) is:

$$R = (X_1 - X_2) \qquad (7)$$

Where X1 and X2 are the analytical results for the duplicates. This provides an estimate of the standard deviation in concentration units (CU). In most cases, R will be directly proportional to X. This is undesirable because a statistic is sought that will represent the precision of any data point, regardless of its magnitude. It is therefore customary to normalize the range, and obtain the Relative Range (also called relative percent difference, or RPD) according to equation 6 (Section 14.3) repeated here for convenience:

$$R\% = 100\ R/\bar{X}$$

This provides a measure of variability, expressed in percent of concentration that is theoretically the same for every measurement in the set represented by the duplicate pair.

14.5.2 One Field Replicate

Occasionally, field replicates are collected and analyzed to provide three or more results for the same point in such a case, the sample standard deviation should be calculated (Eq. 3, Section 14.3), and the precision should be expressed as the co-efficient of variation (Eq. 5, Section 14.3).

14.5.3 More Than One Field Duplicate

When two or more field duplicate pairs are available, precision can be reported as the percent relative range (R%), or as an estimate of the standard deviation. Percent relative range is determined by calculating R% for each duplicate pair, as in 14.5.1, and then computing the arithmetic mean of these values (Table 14-1(A)).

If an estimate of the standard deviation is desired, this can be calculated as a percent or in the units of measurement. The desirable procedure is one that provides a constant precision value across the range of measurements. That is, if R is not dependent on X, then one value can be computed in the units of measurement that will represent precision for the range of X (Table 14-1 (B)). If R is dependent on X, then the value reported in the units of measurement will vary with the magnitude of X. When this is the case, it may be better to report precision as a percent, or a relative standard deviation ((RSD) Table 14-1 (C)).

14.5.4 Two or More Field Replicates

Perhaps the best estimate of data precision is obtained when several samples are collected and analyzed in replicate (see Table 14-2). In such a case, the standard deviation and co-efficient of variance of each replicate set can be computed as in Section 14.5.3. The pooled standard deviation or the average of the co-efficients of variance may then be used to represent the data precision. Again, the object is to obtain a single value that best represents the precision of all the measurements, regardless of magnitude. Therefore, if the standard deviation is not dependent on the mean, then pooled standard deviation is the desired statistic. If dependence is apparent, the co-efficient of variance will be preferred.

14.5.5 No Field or Laboratory Duplicates or Replicates

When there are no duplicate or replicate sample analyses, other data may be available for estimating precision. If the laboratory maintains quality control charts or performs routine analyses of quality assurance samples, the analytical precision can be estimated for parameters analyzed in the control samples. However, such information cannot be used as a valid representation of the precision of measurement data because significant sources of variability are not represented (e.g. sample collection and handling, matrix interferences, etc.).

TABLE 14-1
PRECISION FROM TWO OR MORE DUPLICATE PAIRS
(A) AVERAGE RELATIVE RANGE

DUPLICATES							
X_1	**X_2**	**Range (R)**	**R^2**	**$\overline{X}$**	**R%**	**$R\%^2$**	**Average R%**
41 mg/l	52 mg/l	11	121	46.5	24%	576	
22 mg/l	17 mg/l	5	25	19.5	26%	676	26%
68 mg/l	50 mg/l	18	324	59.0	30%	900	
55 mg/l	69 mg/l	14	196	62.0	23%	529	

ESTIMATING THE STANDARD DEVIATION

(B) When (R) is not dependent on X:

$$S = \left[\frac{\Sigma\ (R^2)}{2n}\right]^{1/} = 9\ mg / l$$

(C) When (R) is dependent on X (RSD):

$$RSD = \left[\frac{\Sigma\ (R\%2)}{2n}\right]^{1/} = 18\%$$

TABLE 14-2
PRECISION FROM TWO OR MORE REPLICATES

(A) CO-EFFICIENT OF VARIANCE

REPLICATES						
X_1	**X_2**	**X_3**	**s**	**$\bar{X}$**	**CV**	**Average CV**
41 mg/l	49 mg/l	52mg/l	5.7	47	12%	
24 mg/l	19 mg/l	17 mg/l	3.6	20	18%	14.8%
67 mg/l	63 mg/l	50 mg/l	8.9	60	15%	
56 mg/l	53 mg/l	69 mg/l	8.5	59	14%	

(B) POOLED STANDARD DEVIATION

$$\left[\frac{3\,(5.7)^2 + 3\,(3.6)^2 + 3\,(8.9)^2 + 3\,(8.5)^2}{12} \right]^{1/} = 7.0 \text{ mg / l}$$

14.6 Reporting Precision

When reporting precision, the meaning of the precision information must be stated. The statement should include the method by which the precision information was derived and the sources of variability that it represents.

It is customary to express precision as a 95% confidence interval. For a normally distributed variable, the 95% confidence interval is expressed as ±2S, and represents the region in which 95% of the sampled population is found. Therefore, any randomly selected sample of the population has a 95% probability of falling within ±2S. When precision information derived by the methods in this chapter is expressed as 95% confidence intervals, two assumptions are made:

1) It is assumed that the variability in replicate measurements fits a normal distribution. That is, if one had an infinite number of replicates and plotted them on a rectangular grid, the result would be a symmetrical "bell-shaped" curve with 95% of the observations with 2S of the mean.

2) The approximations of sample standard deviation used in Section 14.5 yield numbers close to the true sample standard deviation.

For each of the situations treated in Section 14.5, an example of reported precision is presented below (in an actual report, "R" would be the calculated value):

14.6.1 One Field Replicate Pair

The estimated short-term, intra-laboratory (one round of sampling and analysis, and one laboratory) precision of the data is R%, based on analytical results for one field duplicate. The approximate 95% confidence interval for random measurement error present in individual measurements within this sampling round is ±2R%.

14.6.2 One Field Replicate

The estimated short-term, intra-laboratory precision in this case is the standard deviation, S, based on analytical results for one set of field triplicate (or quadruplicate, etc.) samples. The approximate 95% confidence interval for random measurement error present in individual measurements within this sampling round is ±2S.

14.6.3 More Than One Field Duplicate (Table 14-1)

In this case, the data may represent short-term or long-term precision, depending on when the duplicates were collected and analyzed. Short-term means one sampling round, long-term means over several sampling rounds. The short-or-long term intra-laboratory precision is the average relative range, R% = 26%, based on the analytical results of four field duplicate samples. The 95% confidence interval for random measurement error in the individual measurements represented is ±2R = ±52%

14.6.4 Two or More Field Replicates Larger than Pairs (Table 14-2)

This example may also represent short-or-long term precision, depending on when the triplicates were collected and analyzed (see Section 14.6.3). The short-or-long intra-laboratory precision is the average co-efficient of variance, CV = 15%, based on the analysis of four field triplicate samples. The 95% confidence interval for random measurement error in the individual measurements represented is ±2CV = ±30%.

14.7 Estimating and Reporting the Accuracy of Data

The best way to estimate the accuracy of measurement data is to collect and analyze a sample whose true properties are known, and to compare the analytical result to the known value. Although it is relatively easy to analyze a sample with known chemical and physical properties, it is virtually impossible to collect such a sample in the field. The best approximation of this would be to overspike one of a pair of duplicate samples at the time they are collected, and to submit the duplicate pair for analysis. The difference between the analytical result and the known quantity of overspike would then include any bias that is introduced not only in the analytical procedure, but also in sample handling and storage and by the interaction between the analyte and the matrix. This approach can be costly and may not provide much better information than laboratory overspikes, because of errors introduced in the spiking procedure itself.

Typically, the accuracy of measurement data in hazardous waste site investigations is determined from the results of laboratory spiked samples, or fortifications, and is expressed as the sample bias (Section 14.3, Eq. 2).

As with precision reporting, it is necessary to state the derivation and meaning of accuracy data when it is reported.

When only one data point (lab spike, fortification, etc.) is available, the accuracy is reported simply as the bias (see Section 14.3). When several spikes or fortifications have been analyzed with the samples, the accuracy should be expressed as a 95% confidence interval. This can be done in one of two ways, as illustrated in Table 14-3. A spiked sample is a field-collected sample that is spiked with a known quantity of analyte. It must be a duplicate because the quantity already present in the sample before spiking (sample background) must be determined. When the spiked sample and its unspiked duplicate are analyzed, the recovery of the spike is determined by subtracting the sample background (analytical result for unspiked duplicate) from the analytical result for the spiked duplicate. The accuracy for the entire sample set is determined from the mean and standard deviation of all of the spikes, either in terms of percent recovery or relative percent difference, as shown in the table.

In this example, accuracy is reported as percent recovery (or percent bias), based on analytical results for six spiked samples. The 95% confidence interval for percent recovery is 89.6 to 106.0 percent.

TABLE 14-3
ACCURACY FROM SPIKE RECOVERIES

Sample Background (S_i)	**Spike (T_i)**	**Result (A_i)**	**Recovery (A_i-S_i)**	**Percent Recovery (R)**	**Relative Percent Difference (R-100)**
4.0	20.0	22.8	18.8	94.0	-6.0
7.9	20.0	26.2	18.3	91.5	-8.5
1.3	20.0	21.2	19.9	99.5	-0.5
26.3	100.0	128.0	101.7	101.7	+1.7
5.0	20.0	24.8	19.8	99.0	-1.0
34.5	100.0	135.3	100.8	100.8	+0.8

Mean =	97.8	-2.2
Standard Deviation =	4.1	4.1

95% Confidence Internal = Mean ±2s

= 89.6 to 106.0 % Recovery

= -10.4 to +6.0 % Bias

15. TECHNICAL AND PEER REVIEW

15.1 Purpose and General Provisions

This chapter discusses quality assurance measures relevant to interpretive analysis of data and the formulation and reporting of results and conclusions. The needs of clients are not always thoroughly understood when projects are initiated. Also, as project work progresses, the needs may change. Similarly, investigation plans must be devised, data interpreted and conclusions formulated and articulated by a professional without the aid of objective formulae. In these cases, professional judgment and acuity are essential to the successful completion of a project and are dominant factors in the quality of the conclusions. Finally, the ultimate product - the final report - is subject to the above factors, as well as the organizational and compositional skill of the author and the editor, and the effectiveness of the production quality control program.

All of these elements are the subject of the peer reviews and technical reviews discussed in this chapter. Procedures for documenting calculations and reviews of calculations are given in SECOR _________, Numerical Analysis and Peer Review.

An essential feature of the plan is the early initiation of technical and peer review activities in each project to obtain objective assessments of how the project is progressing from the beginning; and to avoid last-minute scheduling difficulties that may create conflicts between review and delivery requirements.

Review procedures for engineering drawings are discussed in Chapter 16.

15.1.1 General Requirements

Each project will have one or more peer reviewers designated at the time of award. In cases where a committee of reviewers is appropriate, one individual will be designated as the committee chairperson. Ideally, the peer reviewer will be a technically qualified staff member from an SECOR line organization separate from the one originating or managing the project to be reviewed. Realistically, recognizing that experts in a field may reside in the same organizational unit, the program requires that the peer reviewer not be directly involved in the work being reviewed. For small projects, a project manager's in-line supervisor also may be appropriate peer reviewer. For large projects, "cross-task" peer reviews are conceivable, where multiple reviewers have project responsibilities, but in separate tasks.

15.1.2 Labor Budget

A labor budget will be set aside for peer review and the appropriate technical reviewing. For most projects, the peer review budget should be a minimum of 3% of the project labor budget. The technical review budget will vary depending on the quantity, complexity, and nature of the product.

15.1.3 Schedule

The peer review and technical review requirements are incorporated specifically in publications scheduling and in any schedules developed for inclusion in proposals or project work plans.

15.2 Responsibilities

15.2.1 The Project Manager is responsible for providing sufficient resources in the project schedule, budget and organization for the appropriate technical and peer reviews, as described in this chapter; and for making sure that complete records of the calculations, interpretations and reviews are filed in the Project File.

15.2.2 The modeling task manager (if applicable) is responsible for assuring that all computer program operations producing results that will be or might be used in the final report are subjected to the appropriate level of technical review, and that the associated records are filed in the Task File.

15.2.3 The data analysis task manager is responsible for ensuring that all calculations (manual or automated), interpretations and conclusions are properly documented and reviewed, and that the appropriate records are filed in the Task File.

15.2.4 The computer program operator or data analyst is responsible for providing documentation of the computer program run or manual calculations to a reviewer for the appropriate type of review, and obtaining a documented review in accordance with this chapter and incorporating the reviewer's recommendations, reconciling any disagreements with the reviewer and filing the records in the Task File.

15.2.5 The lead author of a report or plan is responsible for providing a draft of the complete document to the designated reviewer, obtaining a documented review in accordance with this chapter, incorporating the reviewer's recommendations, reconciling any disagreements with the reviewer and filing the records in the Task File. In cases where no obvious lead author can be identified, the project manager or the appropriate task manager will have this responsibility.

15.2.6 The assigned peer reviewer(s) is(are) responsible for the conduct of the peer review within the allocated and agreed upon budget and schedule. If a peer reviewer does not feel that he/she is being involved in the project to the extent required, the peer reviewer is responsible for calling attention to this issue (errors, omissions must be brought to the attention of the project manager). The peer reviewer will be required to assert that he/she has conducted the peer review in accordance with procedures discussed in this chapter.

15.3 Definitions

15.3.1 Peer Review - A peer review is a review of professional judgments, interpretations and conclusions, conducted by a person other than the originator, but with professional qualifications equivalent to those of the originator. Peer reviews are performed to ensure that a qualified, knowledgeable reader can understand the results and the means by which they were obtained; and, in cases where professional judgment is a dominant factor in the interpretation of data or requirements, to obtain a qualified second opinion from a different perspective to ensure objectivity.

15.3.2 Technical Review - A technical review is a comparison of procedures and results to a predetermined set of criteria by a person other than the originator. Technical reviews are performed on any data analysis that is governed by pre-established procedures and formulae, to verify that the procedures and formulae were used correctly and that the procedures and results are properly documented. Technical reviews of SECOR Standard Operating Procedures are performed by qualified SECOR staff to ensure that the described procedure is complete, valid, and practical (see Chapter 2).

15.3.3 Editorial Review - Editorial reviews of reports, proposals, plans and other publications are conducted to detect production errors such as missing or transposed pages, as well as to detect grammatical, spelling and compositional errors.

15.3.4 Management Review - In some cases, management reviews are required in addition to the above reviews to provide final assurance that a document meets the needs of the project. Specific management review requirements are defined in the relevant project quality assurance plan.

15.4 Review of Proposals, Plans and Reports

15.4.1 Work Plans - Those aspects of proposal or work plan development that involve review of requirements and existing information, formulation of preliminary interpretations and design of investigative, quality assurance and health and safety plans are the subject of this section.

These activities often require professional insight and judgment as well as composition and publication of complex and voluminous documents under difficult schedule and budgetary constraints. Nevertheless, the success of a proposal or project may depend on the quality of these activities. It is therefore imperative that these proposals and plans undergo technical and peer review before being released even as drafts.

15.4.2 Conclusions and Reports - Among the tasks discussed in this chapter, the derivation of conclusions and recommendations from study results probably involves the greatest degree of professional judgment. The consequences of a misinterpretation or misjudgment at this stage can be costly. All reports that contain conclusions and recommendations must undergo peer review and technical review before being published.

15.4.3 Review and Documentation Procedures

PEER REVIEW

By having the peer reviewer involved from the inception, his/her role should be very constructively oriented and compatible with respect to schedules and budgets. It is intended that the peer review process will provide opportunities for independent thought by someone not involved in the day-to-day problems.

The peer reviewer(s) will attend internal kickoff and other significant progress meetings. If none are scheduled by the project manager, the peer reviewer should initiate a meeting. At these meetings, the peer reviewer should be independently determining whether the client's needs are being met and that proper steps are being taken to assure a quality product. The peer reviewer should be on the memorandum distribution list for the project/proposal.

The peer reviewer should be provided with drafts of materials written for ultimate transmittal to clients at as early a stage as possible. This is to specifically avoid having the peer reviewer called at the last moment.

In the peer review, the reviewer should detect and note any:

- Inconsistencies between the project direction or methodologies and the client/project objectives;
- Disagreement with interpretations, conclusions, recommendations and procedures;
- Obscurity of rationale for interpretations, conclusions or recommendations;
- Passages that are unclear, imprecise or misleading; and
- Inadequate or inappropriate citation of references.

The written findings of the review are returned to the originator in one of the following forms:

- A marked-up (in ink) copy of the draft, initialed and dated by the reviewer;
- A handwritten (in ink) or typed memo itemizing the findings, and initialed and dated by the reviewer. The originator either incorporates revisions suggested by the reviewer or works with the reviewer to resolve disagreements. Records of the review and revisions are filed with the final document.

The final responsibility for project product quality rests with the project manager. Unresolved deficiencies in the mind of the peer reviewer should be discussed with the project manager and if necessary with the project manager's supervisor.

TECHNICAL REVIEW

Project plans and reports should also undergo technical review to verify that their format and content satisfy criteria dictated by SECOR, client or regulatory agency protocols. This review can be done as part of the peer review. The reviewer should refer directly the SECOR, client or agency specifications and note any deviation. Records of the review are filed with the final document.

EDITORIAL REVIEW

In addition to the technical content and format of reports, it is necessary to ensure that publications do not contain typographical errors, pagination errors, confusing references, missing pages and other production errors. This accomplished by a pre-press editorial review of the complete master, including the cover, tile page, table of contents, list of tables (if applicable), list of figures (if applicable), all sections of text, references and appendices.

Finally, a random sample of the printed product (at least one complete copy) should be reviewed to detect any printing collation or binding errors.

15.5 Review of Numerical Analyses

Misinterpretations and misguided conclusions and recommendations can results from errors in data analysis, it is therefore essential that all data analyses be reviewed.

15.5.1 Peer review of numerical analyses shall be performed to ensure that appropriate methods were used. This requires peer review because professional judgment is often the most important factor in the selection or design of a numerical analysis method appropriate for the data and circumstances at hand.

15.5.2 Technical review of numerical analyses shall be performed to detect miscalculations, keypunch errors and documentation deficiencies before the results are used in the study.

15.5.3 All numerical analysis and review is performed and documented in accordance with SECOR ________. The calculations and review records are filed in the project-task file.

15.6 Drawings/Illustrations

Drawings that are made to illustrate interpretations of aerial photographs, chemical or physical data (e.g., isopleths of concentration or water table elevation), remedial construction objectives or any other interpretive illustrations shall undergo technical and peer review to ensure that:

- Interpretations are valid and defensible;
- Drawings do not contradict corresponding text discussions or tabulated data;
- Recognized industry standard symbology and terminology are used (e.g., AGI, ANSI, USGS);
- All symbology is explained in a key as part of the illustration;
- Engineering drawing title blocks have the necessary approvals (sign-offs) prior to release, and include the latest revision;
- The illustration is properly labeled with project number, purpose, name of originator, date and revision number (if appropriate); and
- The illustration is of publication quality.

The reviewer is provided with a clean, numbered copy (review print) of the illustration, along with related data tabulations and text discussions. The reviewer notes remarks and recommendations in ink on the review print, signs and dates the marked-up review print and returns it to the originator. The originator incorporates the reviewer's recommendations and, if necessary, reconciles any disagreements with the reviewer. The master drawing is filed in a central drawing file or in the project file. The numbered review prints are filed in the project-task file.

Any future revisions must also undergo review.

Detailed procedures for engineering drawings are given in Chapter 16.

16. ENGINEERING DRAWINGS

(Reserved)

17. PUBLICATIONS

(Reserved)